DIALOGUES
ON
QUANTUM PHYSICS

From Paradoxes to Nonlinearity

By

J. R. Croca and R. N. Moreira

J. R. Croca, PhD in Theoretical Physics, professor and researcher at the University of Lisbon, he focuses his activity on the Fundamentals of Quantum Physics. He is the author of numerous works on the modern causal and nonlinear quantum physics, most of which have been published in international reviews in this field. By invitation from the editor, he recently authored the book *Towards a nonlinear quantum physics* (World Scientific Publishing).

R. N. Moreira, He graduated in Mechanical Engineering, Applied Thermodynamics branch. He did the training and registered in the Order of Engineers. However, he sought to know the fundamentals of engineering in greater detail, having thus decided to attend the Physics course at the Faculty of Science of the Lisbon University. He ended up trying to understand the basis of scientific activity, taking a PhD degree in History and Philosophy of Science at the Lisbon University.

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The authors dedicate this work to the young minds with a free, generous, and entrepreneur spirit, unattached from dogmatic, obscure and conservative prejudgments. They are the heralds of the true progress.

To my firstborn grandson
José

J. R. Croca

To my wife
Guida

R. N. Moreira

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J. R. Croca

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FCT: Fundação para a Ciência e a Tecnologia - Foundation for Science and Technology.

POCTI: Programa Operacional "Ciência, Tecnologia, Inovação" - "Science, Technology, Innovation" Operational Programme;

INTRODUCTORY NOTE

The book now being published came about due to a necessity currently felt in the spreading of new scientific ideas among the general public.

We lack works that are, directly or indirectly, uncompromised regarding religious, political, sectary, corporate or any other dogmas.

Presently, we are witnessing the systematic attack of these more or less occult forces on science.

On the other hand, we would also like to provide the general public with trustworthy and pertinent information on the true ideas underlying the common vision of quantum mechanics. Moreover, we will demonstrate that such ideas, which do not allow us to accept the existence of an objective reality, have already been overcome by the causal nonlinear theory. Thus, we will show our readers that the current worn out of quantum mechanics can and should be replaced by a new casual nonlinear quantum physics, in which the starting point, the basic assumption, is accepting the existence of a reality independent form the observer.

In this context, we shall introduce the reader to a whole new causal and nonlinear physics. This new nonlinear quantum physics contains, from a formal point of view and in its linear statistical approach, the old orthodox quantum physics.

Likewise, we shall present experimental evidence, clearly proving that the old orthodox paradigm is worn out. The mysteries, paradoxes and enigmas so boastfully presented in usual literature are deciphered, in a particularly simple and intuitive way, in the framework of the a nonlinear causal quantum physics.

This new causal nonlinear physics is developed in its fundamentals, in a book recently published by one of the authors (J. R. Croca), entitled *Towards a non linear quantum physics* and edited by World Scientific.

Nonetheless, we do understand that in order to reach a wider public audience, it would be useful to present, on one hand a more simplified version formalistically speaking; on the other hand a more consolidated version, from a historic point of view. Thus, in this work we have tried to eliminate, as much as possible, the mathematical formalism, and also to develop and to further deepen the historic origins of modern science.

A SORT OF INTRODUCTION

These Dialogues I now have the pleasure of presenting to the reader interest in science and culture correspond to a set of discussion meetings I have carefully noted throughout a certain period in time. I will begin by asking for the reader's indulgence regarding my somewhat boorish and rough prose. This derives from the fact that I am not a man of writing and have always had a vocation for technological subjects, possibly by professional deformation, since I work as an engineer. In spite of having had, more contact with managerial problems, mainly technological ones, I have still taken an interest in the most fundamental aspects of science. The lack of time together with family pressures and the need to strive for subsistence have always prevented me from dedicating more time to that fascinating theme which is the basis of our scientific knowledge. Now that I have reached a more comfortable position in life I can dedicate more time to this ancient passion. Truth be told, I have never given up on that passion since my interest in getting to know the root of all things – trying to reach the core of things – have always accompanied me, and perhaps may have even been the reason for my professional successes.

The small amount of information I had on the basis of science derived mainly from reading scientific articles and newspapers, college books and my conversations with a few teachers who, more or less openly, did more than just follow textbooks. As we know, many times subjects are presented in a completely uncritical manner. Science is presented as a perfectly completed body of knowledge where there is no place for doubt. The history of science, in such perspective, constitutes an adventure in which the good guys always win, and the development and the progress of science are an admirably linear clear path, perfectly defined, with no highs and lows.

From my modest point of view, I have always thought this vision of science, besides being reductive, is extremely castrating. However, recognizing my great ignorance in such subjects has always prevented me from manifesting an opinion. This situation has changed in the past few years for I have been fortunate enough as to find someone with an attitude entirely like mine; except, while I have dedicated most of my life, so to speak, to saving money for a comfortable future, that man, who I now consider a friend, oriented his life especially towards the pursuit of knowledge. Through this dear friend I have met other people, also interested in such subjects. From this common interest derived, and I say this not without some pride, due to the full success of my efforts, a series of meetings in several places, where one way or another we always ended up falling into a advantageous discussion on the basis of science, emphasizing that strange and simultaneously fascinating theme that is the basis of quantum physics.

These dialogues are, so to speak, the narration of such discussion journeys which I conscientiously recorded in time and now faithfully put in writing, so that the interested reader can also benefit from these conversations.

Trying to make the debate a little more impersonal, and at the same time preserving the anonymity of the participants, I have decided to give every intervenient a Latin name, including myself. I tried to give each one a name that was, as much as possible, in agreement with his position in the world, his view over science and knowledge in general. To illustrate it, I will only refer to the names I gave myself and my friend. As for the meaning of the remainder, I believe it can be perfectly inferred from the context of the dialogues. For myself I have chosen the name of Liberius, since I have always been a freedom lover. I do consider, perhaps boldly, that I have a spirit which is open to the innovation and progress of knowledge. I believe that, in present times, this attitude is not as common as we are often led to believe. Generally, the very much commented freedom of thought is no more that a mask hiding more or less disguised conformation, and above all, a great reluctance in accepting all that is, in fact, innovative. This is, indeed, more to resemble than to actually *be*. To my dear friend I gave the name Argus. This choice has to do mainly with the fact that he, like the Greek mythology ship of the same name, against all hardships, against winds and tides, is committed in the quest for Truth.

Liberius

HISTORY AND EPISTEMOLOGY

FIRST JOURNEY

It was Friday evening. I had laid the book down and leaned back on the sofa. The book's theme was about foundations of Quantum Mechanics. It tackled a strange relationship between sciences, Quantum Mechanics in this case, and oriental religions. The least I can say is that I was impressed. Was it really possible that modern Quantum Physics was indeed intrinsically linked to mystical, magical and religious conceptions, capable of granting man, deeds that have been considered until then appanage of the gods and other divine entities? Amongst such remarkable deeds I will only state as an example the ability to go back and forth in time and to interact with other physical systems, as distant as they may be, without any need for physical connection!

The phone rang. I left my thoughts in order to engage into the prosaic act of answering a phone call. It was Argus on the other end of the line.

- Hi Liberius, how are you? I have called to tell you that tomorrow, Saturday, I can have lunch with you! As arranged I am also bringing some friends of mine.
- Great! But where do you want to go for lunch?
- Well, I will leave that to you. I am sure you know a place where we can have some nice Portuguese food.
- In that case, we will go to Alcácer do Sal and as you well know, it is an excellent excuse to have a nice relaxed conversation. Besides that, I would like you to try the famous fish soup they serve there. It will take us about one hour from Lisbon to Alcácer. We can leave around noon.
- Deal – said Argus. – We will meet in the café next to your house around half past eleven.

I have put the phone down. And stood there imagining that those plans sounded extremely pleasant.

I then returned to my previous thoughts. In my modest opinion, I have always considered that one should never mix science with religion. However, this scientific information book, apparently written by an accredited author, defended precisely the opposite theory and that left me bewildered and even disturbed.

However, more urgent problems diverted my attention. I had to finish a budget for a 50 ton crane requested by a company from us. Work I had left to do at home.

I arrived at the café at half past eleven the next day. It's a café in Campo Grande. I was the first to arrive. Something I was already expecting to happen as I live in the same building. I bought a newspaper and asked for a bottle of water to justify using the table. During the next ten minutes several people arrived and three of them sat at a table next to mine. One of them had bought a newspaper and all of them had asked for coffee. Each one of them took a detachable part of the newspaper –as it is quite usual for any weekend newspaper to have several supplements – they dived into their reading activity.

My friend Argus arrived five minutes later and in a visibly good mood he said:

- I did not know you all knew each other.

I looked at him surprised and noticed he was not only looking at me, but also at the table next to me.

Both myself and the members of the other table realised straight away that we were all going to Alcácer.

The introductions were swift. Fabrus was a Professor of Physics, the same as Argus, at the University of Lisbon. I was then informed that Amadeus was a well known publisher and Lucius was a technician superior and also a writer of some published works.

Soon informality started to settle in. They were all good hearted people.

I expected, and everyone seemed to agree that I should take my car. Argus knew very well I am content to only drink water during a meal. I knew that would be hard on them. This way the return trip would be made without any problem.

We left at the scheduled time and headed to Vasco da Gama bridge. The wide Tejo estuary looked beautiful on that sunny June morning. The bridge itself helped set the landscape. We kept quiet, maybe so that nothing we would say could ruin the peaceful moment invoked by the landscape. The Vasco da Gama bridge, at almost eighteen kilometres long, took about ten minutes to cross within the speed allowed. Ten minutes of complete silence.

Right after the crossing the conversation sparked into life as if an alarm clock had woken us up. Lucius had started it.

- What a wonderful day! Let's hope the rest of the day doesn't ruin these moments.

- Let's hope so… - answered Amadeus. – This landscape is beautiful from every angle. I had already enjoyed this scenery whilst sailing. Passing under this bridge and going up the Tejo until Valada is also a very pleasant experience.

Fabrus entered into the conversation.

- Argus already told me you like sailing - he said. – I do as well. Also you should know, that although Argus does not sail, he likes it. I don't know if you know that Bohr, certainly the most important physicist of the 20th century, also liked sailing. Heisenberg describes that, together with Bohr and others, he discussed basics of Quantum Mechanics whilst their sail boat travelled the trail and left the reflection of the sun setting over the waters surface. There must have been moments similar to the ones we have just experienced, and it should have be even more interesting to have listened to those dialogues.

- Why do you say Bohr was the greatest physicist of the 20th century? – asked Amadeus.

- Aren't you forgetting Einstein? – added Lucius.

- No! Bohr's ideas shaped extensively the way physicists looked at the world so that the 20th century will be remembered as the century of Bohr in as far as Physics is concerned! In the same way that the 18th century will be considered Newton's century – defended Fabrus.

- I agree with you – said Argus. – But many people may find your statement quite weird. Many shall even doubt it because, like Lucius, they will think you're being unfair towards Einstein. I know you're not forgetting him with your statements. We have discussed this previously several times and we agree with each other. Einstein did not agree with Bohr's positions as they were quite controversial numerous times. As we know, Einstein always lost the argument, at least provisionally…

- I agree with you till your "provisionally" - replied Fabrus. - I think that nowadays it's quite obvious that Bohr and his interpretation of the quantum formalism is strong enough and totally in accordance with what we observe, so that we could understand the reason why Einstein could never have won his discussions with Bohr. Neither will anyone who defends similar points of view, now or in the future!

- Here is the kernel of the disagreement! – answered Argus. – Firstly, in order to avoid any confusion, it’s necessary to underline that I don't defend that Quantum Mechanics is wrong! No one, gifted with common sense, can state that. And for that simple reason Quantum Mechanics has overcome what I consider to be the last validation criteria for a scientific theory.

When a theory allows us to build new tools, tools that couldn’t even be conceived without it, when that theory increases our action ability in the world, it can never be considered wrong.

We can admit, such as we do presently with Newton’s mechanics, that it has a limited application domain. However, after that validation criterion has been overcome, I can state that there is some harmony between the world and what we think about it and that is, deep down, what this theory expresses. But we have to watch out. Between the world and what I think about it, in this theory, there is never an identity relationship. There is only an analogy relationship.

We cannot make the same naïve mistake that, for example, the 18th century Newtonians made by identifying the world by means of Newtonian mechanics. Laplace was led to say that the world was completely determined and that our feelings of possessing free will were pure illusion.

If we identify Quantum Mechanics with the world we’re making exactly the same mistake. We would have to say that Quantum Mechanics is a complete theory and accept the philosophical assumptions that fulfil its basis, i.e. the Principle of Complementarity.

In that case, from Einstein’s undeniable defeat to the statement that Bohr was right goes a long hard way. It was difficult for Einstein to beat Bohr due to the fact he left himself entangled (and it was inevitable not to) in what we can call Bohr’s web. Once one falls there, one can never escape. If we accept Bohr’s game rules, we fall into a trap. Presently we do understand the reason for Einstein's failure. He did not have the empirical information or the new theoretical tools that we have these days.

- I’m not sure you’re right – answered Fabrus. – I think that Bohr is a unique case. He discovered a way to express the limits for our capability of understanding what surrounds us. I’m firmly convinced of that. The new theoretical tools you talk about did not prove to be capable of replacing the quantum mechanics interpreted in the way which Bohr did.

- Oh, Fabrus! What understanding capability are you talking about? - asked Amadeus.

- I’m talking about the impossibility expressed by means of the principle that constitutes the "touchstone" of the Bohrian interpretation regarding Quantum Mechanics and that I've stated before, the Principle of Complementarity – stated Fabrus.

- I’ve never heard that before! – answered Amadeus.

- Neither have I! – added Lucius.

I kept quiet, but my ignorance was as huge as theirs.

- You’re not the only one – intervened Argus. – Fabrus and I have been discussing these subjects for many years, we are obligated to know. I can add that even some physicists using Quantum Mechanics as a tool do not worry too much about that principle, or have even heard about it. In the university textbooks from which one studies Quantum Mechanics, in a general way, these subjects are not explicit. They state the so called principle of uncertainty of Heisenberg, but do not mention its framing in a determined philosophical conception expressed through the Principle of Complementarity of Bohr.

- Can you explain that better? - requested Lucius.

- It’s a long story. I don’t know if you’re interested in listening to the whole story – intervened Argus.

- I’m interested – said Amadeus.

- So am I – added Lucius.

I didn’t say anything, but I was equally interested.

- Where can we begin? – asked Argus.

- Don’t tell me you want to begin in Greece? – questioned Fabrus with a playful look.

- It’s not such a bad idea, but I think that for now we don't need to go back so far! - answered Argus in the same tone.

- If we went back to Classic Greece maybe we could support this with something we really know quite well – dared saying Amadeus.

- We’ll get there, but can we start by asking a question: do you know what the scientific revolution of the 17^{th} century was?

Lucius answered:

- We know what any informed person knows. The important role of men such as Copernicus, Galileo, Descartes and Newton, culminating with the latter theory regarding gravitation and mechanics.

- Of course. Being said in such a general way, one undoubtedly hits the target! But if we want to deeply understand what the scientific revolution of the 17^{th} century was we must look to what has happened in a more detailed way – said Argus, adding: - Galileo was the turning point of that same revolution. It’s not for nothing that we consider him the father of modern Physics. It was he who initiated the understanding of Physics in the way we see it today.

- When he start looking at the sky with the telescope? - asked Lucius.

- That’s the episode most people know about – recognized Fabrus.

- But that’s not Galileo's major contribution. Of course it was very important for him to look at the sky. He intended to gather empirical arguments that supported the Copernican system – added Argus.

- That system defended the theory that the Earth moved around the Sun and not the other way around! - stated Lucius.

- Exactly – supported Argus, adding: - Galileo suspected that was the real system. I would say, he needed that to be the real system.

- Why do you say that? – asked Amadeus.

- Did you know that Galileo wrote a letter in 1604 to Paolo Sarpi, a priest friend of his from Venice, where he almost completely announced the Law of Fall of the Bodies?

- Of course I didn’t know. But I don’t understand what is your point – answered Amadeus.

- Do you know in what year Galileo wrote his famous *Sidereus Nuncius*? The book was written in 1610 in it he reports his first observations made with his famous telescope! A telescope that he built himself, but that hadn't been invented by him! - stated Argus, continuing: - As one knows, in 1609 through a former student of his, Galileo found out about a recent invention made in Holland.

He started to build a telescope that same minute and during the second attempt he managed to build one that might be compared today to a good pair of binoculars that any of us can buy in the appropriate stores.

Then I dared to ask:

- Why was Galileo the first one to immediately use the telescope to observe the skies? Didn't the Dutch opticians who invented it make a previous model?

- I don't know – answered Argus. – Maybe they did, but if so, as far as I know, they didn't report those observations. Besides that, Galileo knew full well what he was looking for when he admired the skies through that telescope! He was already a Copernican and wanted to get some arguments to defend that world system!

- And he did it! – added Lucius.

- I don't know… - answered Argus. – It depends on the way we look at the Copernican system! If we look to the Copernican system summarizing it to the alternative of the Earth moving or not, such as it was defended by the Aristotle-Ptolemaic system or by the Tycho Brahe system, we must conclude that Galileo wasn't that successful!

- What? – asked Lucius almost indignant. – I think we all know what the Aristotle-Ptolemaic system consists of. In this system the Earth is immobile in the centre of the Cosmos, the Moon rotates around it, then Mercury, Venus, the Sun, Mars, Jupiter, Saturn and, finally, the fixed stars' sphere. Regarding the Tycho Brahe system, I don't completely know what that's about and I suspect my ignorance has many partners!

- It's important to know the Tycho system – continued Argus - because without considering this system, it becomes more difficult to understand what Galileo has truly done. We would be mislead to conclude that Galileo's observations would have proven, without any shadow of a doubt, that the Copernican system was correct and that the Aristotle-Ptolemaic system was wrong, concluding therefore the Earth was moving.

- Ah! So it's true that Galileo's observations proved the Aristotle-Ptolemaic system was wrong! – said Lucius more at ease.

- Yes. It's true. But that's not what I mentioned earlier on. Although Galileo did prove the Aristotle-Ptolemaic system was wrong, he didn't manage to unequivocally demonstrate the Earth was moving by means of his observations!

- Why do you say that? – asked Lucius.

- Because the Thycho system, in which the Earth stood still, described as well as Copernicus' the observations Galileo made! As a matter of fact, after good analysis, it explained clearer than Copernicus the observations made so far regarding the movement of the stars and the planets.

- So what was the Tycho system? – asked Lucius, curious.

- In that system – answered Argus – the Earth stood still in the centre of the Cosmos, the Moon revolved around it, as well as the Sun, but the planets revolved around the Sun. This means that from a purely cinematic point of view, i.e. from a point of view that merely describes the movements, these two systems, Copernicus' and Tycho's, were the equivalent of each other!

- And can that be explained with an example? – asked Lucius.

- Yes. But in that case I will have to make some simple drawings – answered Argus.

- Have you noticed we're almost arriving at Alcácer? - interrupted Fabrus.

- Maybe it's better to wait until we arrive at the restaurant in order to make the drawings. We can ask for a piece of paper or even a napkin will do – concluded Argus.

We had already left the highway and we were going down through the final part of the route. When arriving at the roundabout to the entrance of Alcácer, we followed the right hand side alongside the Sado's river bank. After passing the park we turned right on the first road and went up for a couple of yards. We finally arrived at the small and quiet square where the restaurant was situated. The day had got warmer during the trip. However, due to the air-conditioning in the car we hadn't realised that. As soon as we opened a door, we were invaded by a rush of hot air. We left the car quickly and entered the restaurant. It wasn't hot inside. The restaurant's building was facing north and had many houses next to it on the southern side. One could truly say it was really fresh. We were given a table for six in a corner and we sat down. We didn’t ask for anything. I had already ordered fish soup for six people when I called the restaurant before leaving home. I was a regular.

Lucius began the conversation:

- You can make the drawings now – he said, staring at Argus.

- Yes. Can you lend me a pen? – asked Argus. I lent him mine and he started to draw. - Here we have the Ptolemy’s system, Fig.J1.1, with the Earth standing immobile in the centre:

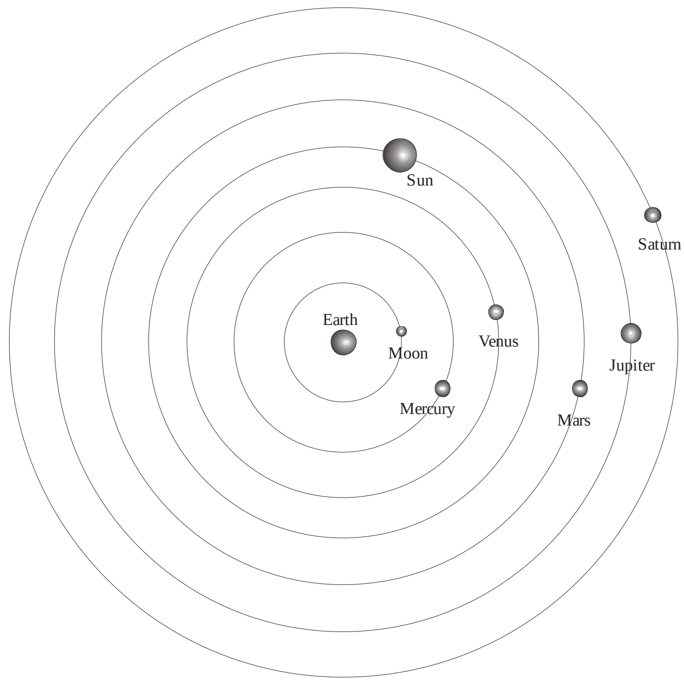


Fig. J1.1 – Ptolemy’s System

The drawing I’m about to do now will represent the Copernicus' system with the Sun standing still in the centre:

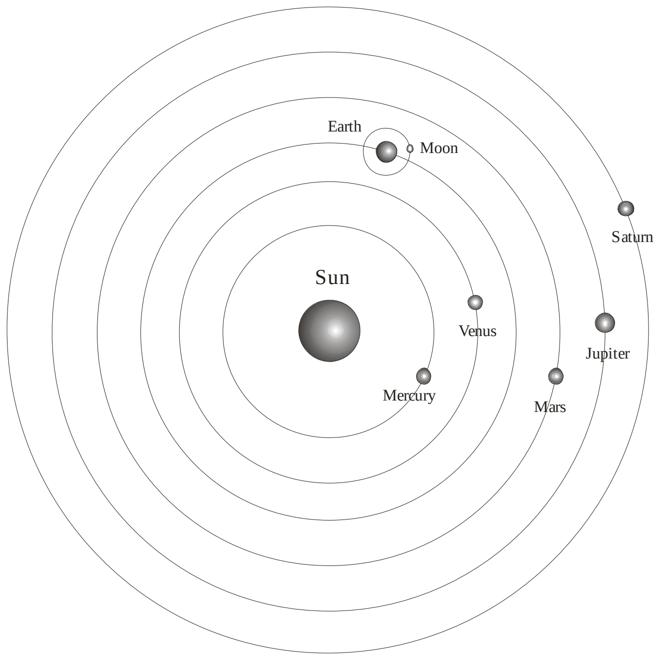


Fig. J1.2 - Copernicus' System

Tycho Brahe's system is slightly different:

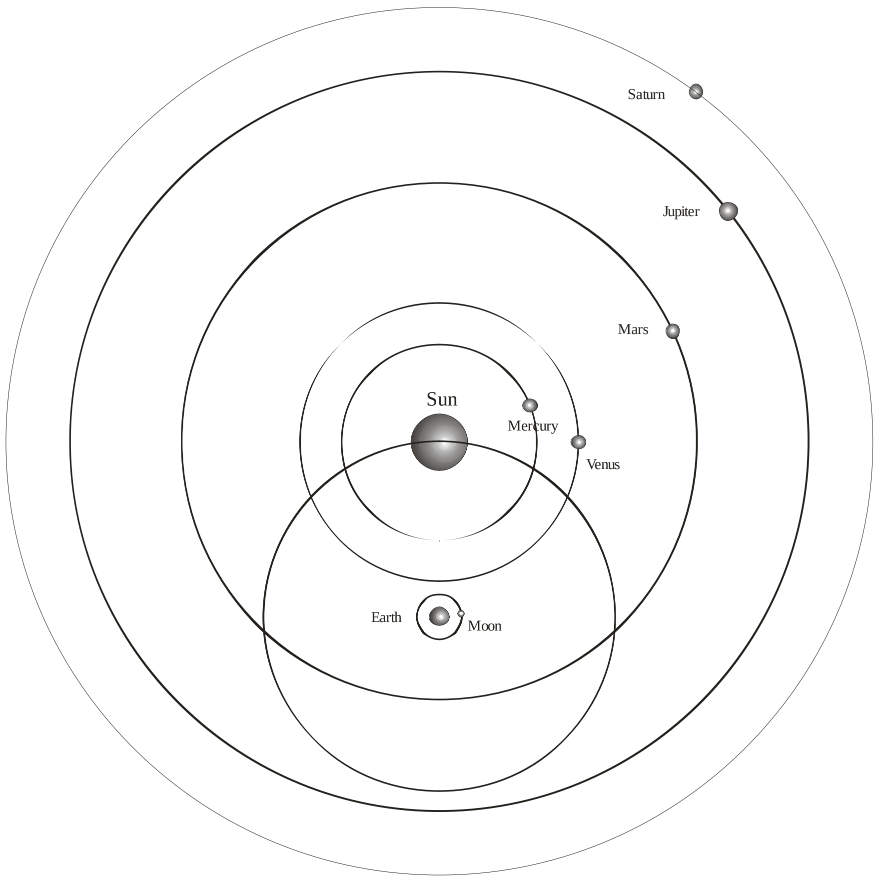


Fig. J1.3 – Tycho Brahe's hybrid system

As one can see, the Earth is in the centre, and the Moon, with the Sun, rotate around the Earth. In this model, the planets rotate directly around the Sun and indirectly around the Earth. As you can see, it’s a hybrid model.

Proceeding, Argus said:

- The example I wanted to tell you about concerns the Venus’ phases such as Galileo observed and that I intend to represent here:

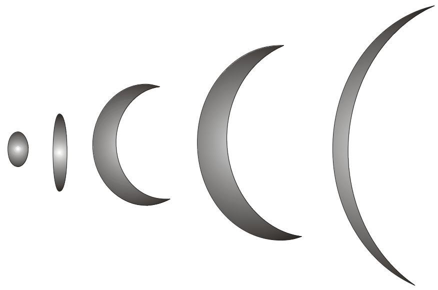


Fig. J1.4 – Venus’ phases

As you can see in this picture when Venus is more illuminated it appears to be smaller and when it’s darker it appears to be bigger.

- Why did you mention that? – asked Amadeus.

- Because this observation is a strong argument against the Aristotle-Ptolemaic system. Notice the drawing that represents the Aristotle-Ptolemaic system. They have represented Venus and Mercury epicycles. The other planet's epicycles are not represented to not complicate the drawing. Venus moved over the epicycle whose centre circulated around another bigger circle centred in the Earth, the deferente. As we can see, in this system, Venus is never further away from the Earth as much as it is from the Sun. This way, it could have never been so illuminated such as Galileo observed. This happened when its apparent dimension was smaller. In this situation, Venus would be further away from the Earth and beyond the Sun. Only in that way it would look smaller and more illuminated. We wouldn’t see it as a circular form, because both Venus and Earth orbits don‘t match and besides that Venus should be aligned with the Sun and beyond it, and under those conditions we wouldn’t be able to observe it. But these are details because what really matters is to conclude that the Venus phases are “mortal” for the Aristotle-Ptolemaic system, but they aren’t at all for the Tycho system. And in this system the Earth stood still in the centre of the Cosmos!

We can therefore conclude that the Venus phases can be considered as the decisive argument against the Aristotle-Ptolemaic model, but didn’t refute Tycho’s model. None of Galileo’s observations showed clearly the Earth was moving!

- But, as far as I know, Galileo was convicted for defending the Copernican system in which the Earth is moving! – exclaimed Lucius.

- Yes – answered Argus, adding: - And that makes us ask the following: why did Galileo start an enormous propaganda campaign, and that’s the exact term, in favour of the Copernican system since 1610?

- I already thought about that – added Fabrus. – Galileo only made public his work on Physics in 1638, already under house arrest, sentenced for a conviction during the famous proceedings of 1633, meaning four years before his death he published the book *The Discourses and Mathematical Demonstrations Relating to Two New Sciences*.

- Exactly – agreed Argus, adding: - As a matter of fact, Galileo published in 1610 the book *The Starry Messenger* in which he detailed his first observations with the telescope. As a consequence, he was tried by the Inquisition in 1615, being intimidated to keep silent and to not defend the Copernican thesis anymore. Shortly after, Copernicus' *On the Revolutions of the Celestial Orbs* was finally added to the forbidden books' list, the famous Index. In 1623, Galileo published the book *Il saggiatore*, where he defends a new way of making science, a new epistemology – the book that presents the famous thought I know by heart:

"Philosophy is written in that great book which ever lies before our eyes - I mean the universe - but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. This book is written in a mathematical language, and the symbols are triangles, circles and other geometrical figures, without whose help it is humanly impossible to comprehend a single word of it, and without which one wanders in vain though a dark labyrinth."

- Famous thought! – added Fabrus.

- Exactly – answered Argus, continuing: - An important book, this *Il saggiatore*, that's not mentioned as much as the previous two I told you about. Nor like the one Galileo published in 1632 and we all know, the famous *Dialogues Concerning the Two Chief World Systems.* A book that tenaciously defends the Copernican system. The book that triggered the second proceedings by the Inquisition.

- So Galileo published *The Starry Messenger* in 1610, *Il saggiatore* in 1623, *The Dialogues Concerning the Two Chief World Systems* in 1632 and *The Discourses and Mathematical Demonstrations Relating to Two New Sciences* in 1638? – asked Lucius trying to sift up all that information.

- Yes, if we don't consider minor works such as, for example, *La bilancetta*, a youth work where the influence of the Hellenist Arquimedes was already present – agreed Argus.

- But anyway what was your point? As I seem to remember it, I think you were talking about a question that should be asked! – exclaimed Amadeus.

Argus smiled and explained:

- I was saying that Galileo already knew or was about to know the Law of Fall of the Bodies in 1604 and instead of working on that theme and publishing the results obtained, he decided to unleash a huge propaganda campaign in favour of the Copernican system since 1610. Besides that, I've stated that none of the observations Galileo made with the telescope proved without any shadow of a doubt that the Earth was moving, and as I have already told you Tycho's system explained those observations as well as the Copernican system. And the Tycho's system solved a problem that Copernicus' system didn't. I'm talking about the non observation of the stars' parallaxes.

- We all know it's a parallax error – interrupted Fabrus to explain it. – For example, when we're measuring the length of a ruler we must look perpendicularly to the ruler over the point where we're reading from. If not, we end up introducing a reading error and therefore attribute different lengths to the distance we want to measure. The length we measure depends on the position of observation. It's similar with the stars. In the Copernicus' model the Earth is not still. It rotates around the Sun. The distance between two points with an opposed diameter from their orbit it's around 300 million km. While observing the same star in one of those points and six months later, in the opposite position, we should attribute it different positions.

- And does that happen? – questioned Amadeus.

- Of course! – said Fabrus. – Nowadays, the parallax method even constitutes one of the most accurate methods to determine the distances between the stars and other cosmic objects. In the 17th century that parallax was impossible to observe. The means of observation of that time did not allow it. That only became possible in the 19th century with the construction of better telescopes. But in the 19th century no one longer doubted the Earth's mobility!

- Neither Copernicus or Galileo have managed to answer the criticisms that their adversaries made and that made sense - said Argus, adding: - Copernicus tried to defend himself by stating that the stars should be at a much further distances than it had been admitted until then. But if presently we consider that was a good answer, we must accept that in those days it wasn't very convincing.

Let's see. The stars' parallax wasn't observed and the simplest conclusion was to accept that the Earth was immobile.

In order to explain the non observation of the stars' parallax, admitting that the Earth was indeed moving, we had to place them at distances that at the time were a little unreasonable. Distances that radically broke with the dimensions attributed to the Cosmos until then.

- A complicated problem – agreed Lucius.

- Once more we see that the question to be asked is: If Galileo in the beginning of the century was close to the Law of Fall the Bodies, why didn't he publish those results instead of following the path I referred to before? - asked Argus. - The answer is: so that people would accept the way Galileo reached those results, it was necessary to previously believe in the Copernican system. Why? Because those results were obtained by means of a method that could only be understood if people already believed in that system.

- I don't understand! – said Amadeus.

- It's natural! But to understand this is essential to understand the kernel of the scientific revolution of the 17th century! – answered Argus.

The famous fish soup was arriving at the table. The conversation was interrupted for everyone to observe how it looked. Perfect, as usual. The fish used was ling sided with mint from the river, oreganos, in short… all the seasonings of the worshiped food from Alentejo.

After we served ourselves and started to taste, totally delighted, with the fine delicacy, the conversation restarted. And the initiative came from Amadeus.

- Can you please finish your reasoning now? – he said, turning to Argus.

- I was saying that Galileo needed people to believe in the Copernican system in order to believe in his way of explaining Physics.

- You said that Galileo didn't receive any argument in favour of the Copernican system with his telescope observations. So, if there are no arguments in favour of that theory maybe it wasn't reasonable to defend it - intervened Lucius.

- I didn't say that! – answered Argus, continuing: - I just said that Galileo's observations didn't add any argument in favour of the Earth's mobility. I didn't say there were no arguments in favour of the Copernican system.

- I don't get it! – said Amadeus.

- Ptolomeu's system and Tycho's system defended the Earth's immobility. But they also established an ontological distinction between both worlds that were essentially different.

- I think you're talking about the sensitive world and the intelligible world of Plato – said Lucius and Amadeus almost simultaneously.

- Exactly! – answered Argus. – As you can see, it's impossible not to mention our Greek ancestors! We all know that Eudoxus, one of Plato's disciples, initiated what we could call, using a modern terminology, the first scientific research program built by man. Within the astronomy domain, of course. I'm talking about the homocentric spheres' model that Eudoxus built from the platonic postulation defending that world, that intelligible world, which would participate in the ideas of circularity and uniformity. As we well know, the homocentric spheres model was the first model to be made in order to describe the movement of the stars in the skies.

Later on, Aristotle changed the simplistic model of the homocentric spheres making it more complicated by increasing the number of spheres. Besides that, transformed Eudoxus' geometric spheres into spheres made of a subtly transparent substance. Some centuries later, already during the Hellenistic period, and in accordance with the natural evolution of a scientific research program, the deferent and epicycles' model that I mentioned earlier on was added to the homocentric spheres' model. A model that intended to account for the planets' brilliance variation and that was since the early days associated to the variation of distance from the planets to the Earth. This phenomenon is more evident in the planets that are closer to us, such as Venus and Mars. The homocentric spheres' model didn't manage to explain it, because in that model the planets were always at the same distance from the Earth.

- We don't see much when we look to the skies – added Fabrus. – Our eyes are weak detectors and filter out almost all the information regarding that world. A world that Aristotle called supralunar: a world beyond the Moon. In that world we can only observe luminous points changing position. For the rest, we only observe two bodies with a bigger dimension, the Sun and the Moon, but they are also circular and don't seem to have any other change besides the simplest change of position.

- You forgot to mention that the Moon has phases! – said Amadeus. – But those phases didn't constitute a change in the Moon, and as a simple consequence of that fact the Sun and the Moon alter their relative position and, simultaneously, their positions regarding the Earth.

- Yes, you're right – agreed Argus. – But the most important thing is to recognize that the platonic legacy that considered that world to agree with the circularity and uniformity ideas is the cause of the whole scientific research program that reached a high sophistication degree. I agree with Fabrus when he said that men unconsciously simplified that world. Inadvertently, they thought that in that world the only change was a simple change of position!

And that was the change, that local movement that men dared to describe mathematically. And that was the reason why they considered it an intelligible world.

For the sublunar world where they lived, the world before the Moon, their senses allowed them to learn all kinds of changes: a generational and corrupted world; a world where little keep lasting, starting with man himself; a world where local movements - the simplest change of position – mingled with all types of changes. Besides that, those movements weren't circular and uniform, a characteristic exclusive to the supralunar world movements.

In the sublunar world, movements divided between natural and violent. The natural ones were vertical movements from top to bottom, if the bodies were heavy, and from bottom to top if they were light. They were called natural because the bodies followed a tendency to occupy their natural position, i.e., the heavy bodies, like earth and water, occupied respectively the centre of the world and the contiguous spherical crown, and the light bodies, like air and fire, occupied the superior layers of that same world. And that was the reason why the Earth was located at the centre of the world. That would be its natural place.

On the other hand, violent movements were the movements in which the bodies didn‘t follow a natural trajectory, such as a wagon pulled by a donkey or a stone throne by a sling. Aristotle explained that those movements could only happen if an engine acted permanently on the body, as it was the case of the wagon and the donkey. In this case, the donkey was the engine. But from that arose a problem to explain the projectiles’ trajectory. The sling example is one of them. While the stone keeps in contact with the sling, we can attribute it the part of the movement engine. The problem arose when the stone stopped being in contact with the sling. Aristotle answered to this objection stating that the world has horror to the void and when a projectile moves it makes immediately for the air to occupy the space left by the body, pushing it. Therefore, the air represented simultaneously the engine and the movement resistance. This was the weakest link of the Aristotle Physics and it's natural that the Aristotle followers tried to introduce the concept of impetus. This would be a moving virtue that, for example, in the sling’s case, it would be printed on the stone by the sling itself allowing it to continue moving violently while that impetus didn’t wear out. This was the general picture that integrated the whole Aristotle Physics.

- We all know that Aristotle was the first to build Physics while rehabilitating the senses’ data as a mean to achieve knowledge. It was a coherent Physics with metaphysic. With an ontology where it made sense. It was an explanation of the sublunar world that, as we see, was totally different from the one used to understand the supralunar world - added Fabrus. - A Physics that needed the Earth to rest in the centre of the Cosmos.

- Ah! – said Lucius excited. – So that was the reason that led Galileo to defend the Copernican system in such an obstinate way?

- Yes. That defence of the Copernican system was necessary to fight the Aristotle Physics. But, above all, it was necessary to defend a new way of explaining Physics that Galileo had already started to use! - explained Argus, adding:

- And that’s the key point for one to understand the scientific revolution of 17th century!

- Can you explain that a little bit better? – asked Amadeus.

- I mean that Galileo defended the Copernican system because it imposed an ontological unification of the world. In this system there were no longer two worlds ontologically different, the sensitive world or the sublunar world, and the intelligible world or the supralunar world.

By withdrawing the Earth from the centre of the world, Copernicus, like a wizard’s apprentice, threw it to the middle of the planets. The Earth was thrown into a world in which movements could be mathematically described.

The ancient astronomers did it. They dared to do it because they had only observed a single change in that world, a simple change of position or, if you like, the local movement as the Greeks used to call it. They achieved it because they couldn't have grasped that world the way it really was. They did it because, unconsciously, inadvertently, they had simplified that world.

And Galileo wanted to do the same for the movements on the Earth's surface. For that he had to simplify, this time deliberately, in a premeditated way, the complex world that his senses allowed him to apprehend.

He had to abstract from everything else, from all the other changes, and just look to the simple change of position.

I mean that Galileo understood that the ontological unification imposed by the Copernican system was followed, immediately and inevitably, by an epistemological unification. If now only one world existed, then the way to try to understand it would be inevitably the same. The Earth would start belonging to an intelligible world! The Earth started to belong to a world in which the local movement could be mathematically described!

We can now understand the profound meaning of Galileo's sentence in *Il Saggiatore* that I quoted earlier on. This was the profound reason that led Galileo to develop an enormous propaganda campaign in favour of the Copernican system! This system authorized him to do what he wanted to do: mathematically describe the movements over the Earth's surface!

- I got it – said Lucius before tasting another spoon of the delicious fish soup.

- Me too – added Amadeus.

- As you well know – intervened Fabrus, - Argus and I have already spoken about this subject several times. Both I and he are quite interested about physic's history. I think that Argus is right. Even not having any argument in favour of the Earth's mobility, there was new data that mined the ancestral conviction that there were two ontologically different worlds. As we know, Tycho, who was a meticulous and accurate observer of the skies, had verified that a comet passing near the Earth had followed such a trajectory that it crossed the transparent crystal spheres associated to several planets by Aristotle. These observations showed that the supralunar world wasn't as immutable as it was stated. New stars could appear in it, not observed until then; besides that, the existence of an Aristotle substantiality of those crystal spheres had been questioned for the first time.

As one can easily understand, periodic movement hadn't been associated to comets yet, such as with other stars. The time they take to return to their trajectory points closest to the Earth and the long years during which they remain invisible disallowed for one to admit that those comets were the same ones seen several years before. Besides that, Tycho observed a "Nova", a star that hadn't been visible so far and then, all of a sudden, appeared in the sky. He verified that the "Nova" didn't suffer from parallaxes, indicating it was as distant as the other stars. Once more, there were evidences to show the illegitimacy of assuming the world that Plato considered intelligible, as a world where the only change observed was a simple change of position. A world where the immutability prevailed or, at least, a world where the only change observed, was a mere change of position. So celestial bodies always returned to the points where they had passed before. It's easily understood that Plato's postulate of circularity and uniformity guaranteed it should be so.

- Tycho Brahe's contribution was an important one - added Fabrus - in order to open the way to the ontological unification Galileo needed, although Tycho carried on defending the Earth's immobility.

- Both Copernicus and Tycho – helped Fabrus – represented the role of the wizard's apprentices by opening the way for Galileo to state what neither of them dreamed could ever have been said! And that's why Thomas Kuhn, an important science historian, said Copernicus book was more important for what it forced others to say than for what it has written in it.

- Kepler – added Argus, - also him a Copernican, ended up being responsible for the destruction of Plato's inheritance of circularity and uniformity, by introducing the elliptic orbits for planets and for the Earth itself.

As we all know, the famous three Kepler's laws are by discovering order:

1st The imaginary line that unite the planets to the Sun covers similar areas in similar times.

2nd The planets' orbits are ellipses and the Sun occupies one of the focuses of that ellipse.

These laws were first mentioned in his book *New Astronomy* of 1609.

3rd The square of the planets orbits' period divided by the cube of the average distance of those planets towards the Sun is a constant, i.e. it doesn't change from planet to planet.

This law is presented in his book *The Harmony of the World* of 1619 and the period it talks about is the time the planet takes to rotate around the Sun and which, as we know, for the Earth is 365 days.

- Explain that third law a little bit better – asked Lucius.

- I'm not writing equations because I've disappointed myself once already by trying to explain them to those whom do not know that language much. An old professor of mine told me one day that, many times, physicists and Physics hide behind equations. Although this is the language used by Physics, it's not limited to math. It's necessary to interpret those formulas and that's where the struggle is. If not, any mathematician could be physicist and we all know that doesn't happen - said Argus, adding:

- We don't know how Kepler got there. He didn't tell us that, but he must have made several calculations to obtain that result. During an already difficult period of his life, he gets inspiration to try to achieve what was considered to be the Creator's most profound secret.

As a neo-pitagoric, Kepler believed in an existing harmony in celestial movements, a harmony our ears were so used to they could no longer hear it!

In the end, the harmony he discovered was the harmony for reason and not for senses!

- And was that law so important? - asked Amadeus.

- Very important. Because later it allows Newton to discover his famous universal gravitation law, associating it to the centripetal acceleration law discovered by the Dutchman Huygens and rediscovered by Newton himself.

- Can you explain that better? – asked Lucius.

- I'll try. But in order not to complicate calculations I will admit as a first approach that the planets' orbits are circular. This was the first form Newton used to get there.

Imagine you're in a theme park. As is usual in those parks there are, amongst others, some devices aimed to cause fear or other emotions in people. One of those systems is a sort of cylinder open on the top. People enter the cylinder and then it starts spinning. The people inside it are thrown against the cylinder's wall. It's like a force is pushing a person against the cylinder. And that person will feel more compressed against the wall the larger that cylinder's rotating speed – said Argus.

- Yes, that's true and I've experienced that already - agreed Lucius.

And Argus added:

- Exactly. What the Dutchman Christian Huygens managed was to quantify the acceleration suffered by a body while describing this type of movement.

- You're talking about acceleration, but in a sense a little bit different from mine – interrupted Amadeus and explained: - When I talk about acceleration, I'm referring to what happens when one presses a car's accelerator or when one presses the brake, although in this case we're talking about a deceleration!

- You're right – agreed Argus, explaining: - In Physics, speed isn't just a number, for example, 100 k/h. We must also explicit the direction given to the movement. We change speed by changing that number. We increase it to 120 km/h by pressing the accelerator. We decrease it to 80 km/h when we press the brake. We also change speed when we turn the car's steering wheel, because we're changing our direction. In that situation we also feel acceleration because we're thrown against the seat's edges, meaning to the exterior of the bend we're turning into. When we press the accelerator we're thrown against the car seat, during braking we're thrown against the belt that's fastening us to the seat.

- That's related with the Law of Inertia that Galileo first introduced in Physics. Later on, Descartes and Newton reformulated it, having the latter integrated that law within a much wider frame of his mechanics – intervened Fabrus.

- Yes, we can say that – said Argus -, but while talking about The Law of Inertia and the role Galileo took on in his discovery, I feel compelled to talk again about Galileo. As a matter of fact, it was him who announced The Law of Inertia for the first time, but a different one from the one that Descartes and Newton announced later on.

- So did Galileo made a mistake? - asked Lucius surprised.

- Yes. And not just one – answered Argus, continuing: - He made several ones, as it's natural for a man who was exploring a path that, until then, no one dared to explore. Meaning he was trying to describe mathematically and quantitatively the movements at the Earth's surface. But this was a pretty mistake!

- How's that possible? How can a mistake be pretty? – asked Amadeus, intrigued.

- Because that mistake allowed us to follow and understand the path Galileo walked on to get where he got! – answered Argus, adding: - For Galileo, the inertial movement was the circular and uniform movement, i.e. the perennial movements of the skies being transposed into the Earth. Do you want to know how he got there?

- Of course we do! – said some of us almost in unison.

- Well – said Argus, starting his explanation. – Firstly, Galileo built a pendulum by nailing a nail to the wall and suspending a wire to it with a weight on the lower end.

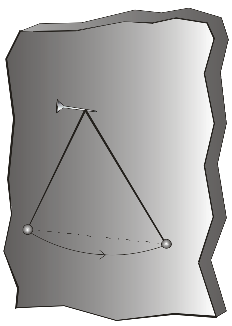


Fig. J1.5 – Pendulum freely oscillating.

Next, he set up a horizontal straight line around a third of the wire's length above the weight in a balance position. Then, he moved the weight to the left maintaining the wire strained until it reached the height of the straight line previously set up. By releasing the weight he saw that it reached the same height after making a circular movement around the upper point of the wire stuck to the nail.

Of course we know the weight doesn't reach exactly that height because the friction of the air and the friction of the wire fixation to the nail causes the pendulum to lose speed and ends up stopping at the end of several oscillations. And that's the reason why we have to wind pendulum clocks. We do it so that it exerts a force in order to compensate for that loss of speed.

Galileo also knew this happened and that the height reached wouldn't be exactly the same. But Galileo wanted to apply those movements to this world and for that he knew he had to change it a bit, he had to bring it nearer as much as possible to the intelligible, mathematical world the Greeks had identified as a supralunar world.

For that, by means of an inductive reasoning, he transformed this world into a world that could be described mathematically. He said that in a world where there was no friction, a world similar to the supralunar world, the pendulum would have reached exactly the same height where it initiated its movement.

Galileo had to adopt this method in order to make this world of ours an intelligible one. A world that had been thrown by Copernicus into the sphere of mathematics. A world that men had dared to describe in a mathematical way a long time ago. As I told you before, they did it because, inadvertently, they looked to a world simplified by the limitations that their eyes imposed on them. Now, he was doing it with premeditation, deliberately. Galileo now simplified that world, because otherwise he couldn't describe it mathematically. Galileo was only looking to the local movement and, even that one that to be simplified. He had to expurgate its "imperfections", the frictions, all which might contradict it. He could therefore assess it by means of the world movements to which the Earth was thrown to, for a world of "perfect" movements, for a world of eternal movements, for a world where movement could be a state, meaning, it could stay. And this was totally against the Aristotle Physics where only rest could be a state. Only rest didn't need a cause to justify it.

- But how did Galileo get there? – asked Lucius slightly anxious.

- I'm sorry, I got carried away - said Argus. - Let's get back to the pendulum I was talking about. After the first experiment, Galileo nailed another nail to the wall at half a distance between the first nail and the horizontal straight line he set previously and vertically that passed by the first nail. Next, he moved the weight to the initial position of the first experiment and released it.

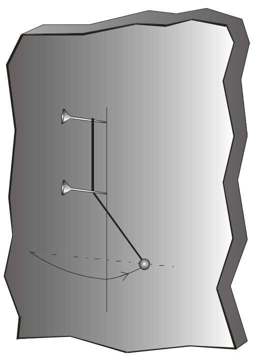


Fig. J1.6 – The weight reaches the same height.

The pendulum made the same circumference as the first experiment until the wire hit the second nail. After that, it started making a circumference of a smaller radius, with a centre in this second nail, reaching however the same height it reached during the first experiment.

Galileo was now ready to presume that the weight dropped from a certain height, without considering frictions, would reach that same height regardless of the route made. But he could made another experience.

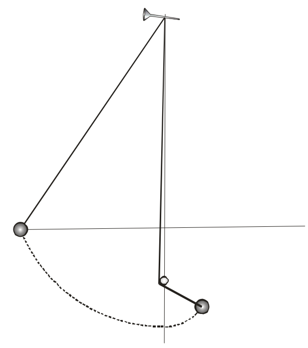


Fig. J1.7 – The weight starts to describe a spiral.

By placing another nail in the vertical position of the pendulum balance below the straight line set up initially, in order for it to remain closer to the pendulum balance position than to that straight line. He would then move the pendulum to the initial position of the previous experiments, releasing it after. Such as in the previous one, the pendulum would describe the same circumference until the wire would hit this last nail. It would then start rotating around that nail in order to reach the height it was released from. And by not doing it so, it would start rotating eternally around that nail if the wire didn't start simultaneously rolling up and the movement stopped.

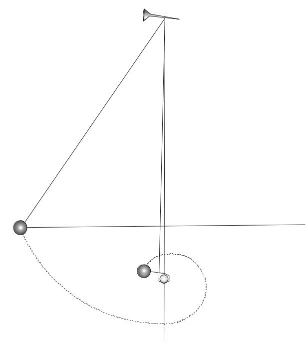


Fig. J1.8 – The weight describes a spiral.

- This is interesting – intervened Amadeus. – But how do you get from there to the Law of Inertia?

- I'm describing the heuristic route followed by Galileo. I haven't finished yet. What Galileo does next is no longer an experiment that can be performed in a lab, it's just a conceptual experience allowed by an inductive reasoning based upon the experiments I've just referred.

Galileo draws on a sheet of paper two inclined planes as if they were the slopes of two hills with a valley in the middle. He then draws again a horizontal straight line that intersects both slopes on the upper part.

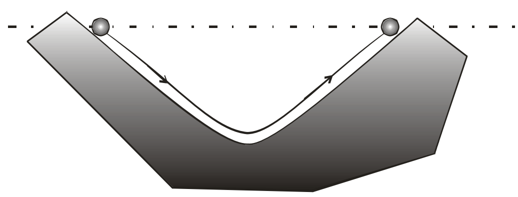


Fig. J1.9 – Two inclined planes.

He admits now that a sphere dropped from a height corresponding to the straight line drawn would fall that slope and should climb the contiguous slope until reaching the same height represented by the horizontal straight line.

- But that doesn't happen! – exclaimed Lucius, surprised.

- Of course not! – agreed Argus. – But what Galileo is doing once more, and in a deliberate way, is to simplify the world! He is admitting that it would be lawful to disregard the effects of the several frictions. If air didn't exist, if the friction between the sphere and both leaned plans didn't exist, then, yes, things would happen the way he described.

- But how did he manage to convince the minds of that time to accept that type of procedure? The Aristotle Physics intended to describe things such as they seemed to be before our senses. The new way of doing Physics, the epistemology that Galileo wanted to impose, didn't want to describe things such as they appeared before our senses. For that time, it should be something difficult to accept! – intervened Amadeus.

- Of course! - answered Argus. - Galileo intended that we abandon the attempt to describe the world such as it appeared to be! He wanted for us to accept the possibility of using other models that could be mathematically described! It was a huge jump that not all minds were set to accept. For that, it was necessary to show them the Earth now belonged to a world that had been, since a long time ago, object of a mathematical description. At least part of it, the local movements that have been, so far, the only change attributed to that world!

We now see why the defence of the Copernican system was directly related with this new epistemology! Now, the creation of mathematical models could be predictably assumed and not inadvertently like the astronomers of classic Greece and the Hellenistic period had done! And that with the exclusive goal of describing the Earth's local movements.

- I understand it now! - cheered up Lucius. – Now I understand how hard it was for Galileo to manage for the "owners" of knowledge to accept this new way of understanding the world that still had so little to offer!

Now I understand why Galileo defended the Copernican system! He did it with the purpose to achieve a new coherence, a new unit of knowledge! Now I start to understand why you always repeat that the defence of an ontological unification was concomitant with the defence of an epistemological unification.

- But you haven't said yet how Galileo reached the Law of Inertia, nor which "pretty" mistake did he make! – I dared to intervene.

- You're right – said Argus. – I apologise once more for having returned to the hard core of all of this. Let's get back to the two inclined planes of the conceptual experience I was telling you about. Galileo could now make a new drawing similar to the first one, with the only difference that the second inclined plane, the one in which the sphere climbs up, is now less inclined intercepting the horizontal straight line furthest than the first inclined plane intercepted it.

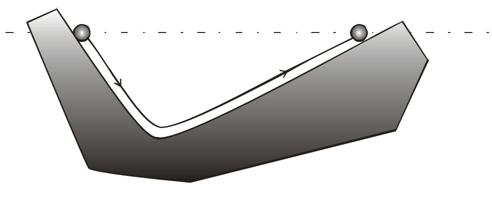


Fig. J1.10 – Two asymmetrical inclined planes.

The sphere dropped at the height correspondent to the horizontal straight line should reach the same height regardless of the route. This way, the sphere would travel a greater distance until reaching the horizontal straight line! Well, now it's easy to guess which drawing he made next. Maintaining the first inclined plane and the horizontal straight line where the movement would start, Galileo drew a new horizontal straight line parallel to the first one in the extension of the lowest part of the initial inclined plane.

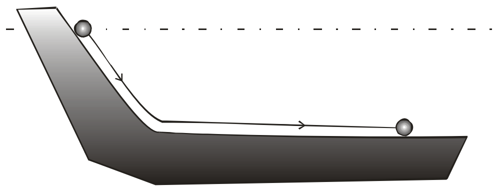


Fig. J1.11 - An inclined plane and a horizontal one.

If the sphere were to be dropped from the height of the horizontal straight line from higher above, the inevitable conclusion would be that the sphere would keep on moving continuously, because under those conditions it would never reach the height where it had fallen from! As one can see, Galileo described phenomena by means of geometrical images. Geometrical images like inclined and horizontal straight lines, curves and spheres. Although using very simple geometric concepts, and elementary geometry, this was already the usage of a mathematical language in order to try to describe the phenomena.

- But you still haven't said which mistake he made, the so-called "pretty mistake" – intervened Fabrus. – As we've seen, Galileo reached the Law of Inertia associated to a straight and uniform movement that Newton would use later on as one of the pillars for his Mechanics and gravitation, the explanation of the stars' movements. We've already discussed this and I know this is where the mistake will appear.

- Exactly – added Argus. – All of this is made at the scale of a lab. Galileo will now attribute dimensions to the inclined planes that are close to the Earth's dimensions. At this scale, the Earth's surface is approximately circular; if the exit plan was horizontal it would start reaching immediately higher heights, ending by reaching the height from where the sphere had started. In that case, for the movement to be able to perpetuate itself, it was necessary for the exit plane to be circular, following the Earth's surface.

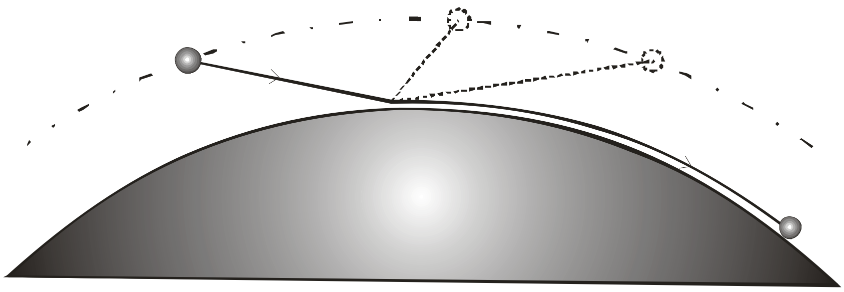


Fig. J1.12 – Law of the circular inertia.

Only in that way, the movement's height would always be kept at the same distance as the centre of the Earth, perpetuating itself. As we can see, Galileo ends up associating the Law of Inertia to the circular and uniform movement.

Those are the perennial movements of the skies coming down to Earth. Or better still, it would be the Earth ascending to the skies, to that supralunar world where perennial movements would be the circular and uniform movements. This way we can see the origin of Galileo’s Physics. It comes falling from the sky. The perennial movements were indeed the circular and uniform movements, both in the Earth and in the skies. This was Galileo’s mistake. But a pretty mistake, because it allows us to see what a profound coherence he was looking to implement. He was unifying sky and Earth's Physics, because the latter had ascended to it by the Copernican system.

The silence settled in. Everyone was thinking and wanting to end the excellent lunch. It had lasted longer than usual, due to the conversation distracting them. All tried to internalize what they have just heard and not even Argus was escaping from that.

We ordered dessert and while we waited Fabrus decided to restart the conversation:

- I think Galileo’s thought became clear as well as his part during the scientific revolution of the 17th century. We all know the problems he had while defending the Copernicus' system when, in a naïve way, he convinced himself capable of persuading the Church to accept that vision of the world.

- Presently, it’s easy to understand that naivety – interrupted Amadeus. – The men from the 17th century were heirs of the Renaissance thought and all of a freedom of thought that an eager recovery of the old knowledge had unleashed. Many believed it was necessary to conciliate that knowledge with the Christian faith. Maybe it was exactly the conjugation of the Greek reasoning with the Christian faith that led so many to believe that was the quickest way to reach God. The neo-platonic Copernicus and the neo-pitagoric Kepler are just some examples of a much wider group of men who believed that fighting the scholastic knowledge that corrupted Aristotle's thought in order to reconcile it with the Christian faith could elevate the Christian faith, giving it the Greek rationalist attitude. As was inevitable, confusion was great, but the final result of it all was the advent of a new attitude that allowed reaching a new way to try to understand the world, modern science.

- You’re right – agreed Argus. - It’s an exciting historical period and very much studied already. We understand this revolution, and here this name perfectly correct, would have been impossible without the assumption of freedom of speech allowed by the Renaissance mentality. Presently, it’s consensual that, without the so called Renaissance magic-natural mentality, without the cultural mix it created, the freedom to try to find new paths would have been impossible.

As we all know, the 16th century was characterized, in a cultural point of view, as being a challenge century. Challenging the cultural power scholars had. Only that way we can understand that in Paris a thesis was presented and accepted defending, with evident exaggeration, all that Aristotle said was wrong. This thesis was defended by Petrus Ramus or Pièrre de la Ramée. I say this to underline that, without exaggerating much, what the 16th century meant leaving as a legacy to the 17th century men was a pile of debris. And these ones, by following several paths, had to find a new way to try to understand the world.

They had to try to get a way to rebuild the edifice of knowledge from new foundations. And that's how modern science emerged. It was Galileo who, in a very consistent way, pointed towards that way. One thinks that the very strong influence that Arquimedes had over him was one of the causes that allowed him to glimpse that way. As we know, Arquimedes was the first one to reach the laws of Physics expressed in a mathematical way. It's undeniable that the Law of the Lever and the Law of Hydrostatic Balance were the first mathematical laws of Physics. But these were laws that translated balance or equilibrium situations, where movement didn't exist, situations of rest. It was Galileo who found the way to extend the application of mathematics to the Earth's movements. In order to do so, it was necessary to have the influence of Arquimedes, but also, as I never get tired of repeating , the glimpse that the Copernicus' system allowed to extend to the Earth's surface movements the method that, since ancient times, was applied to the study of celestial movements.

- Many authors speak of an epistemological cut when speaking of the scientific revolution of the 17^{th} century – said Lucius. – I think that Kuhn uses that term.

- Yes, but I don't agree – answered Argus.

- When talking about an epistemological cut of the scientific revolution of the 17th century, one loses the general picture of its time and one just looks for what happened regarding Physics, the desertion of the Aristotle Physics and the arising of a new Physics.

I think it's unlawful to do so. We must look to everything that happened and, in that case, we must say, as I have said before several times, we will only understand what happened when seeing if it was the ontological unification brought by the Copernican system that dragged the inevitable epistemological unification defended by Galileo. Galileo was only applying the study of the Earth's surface movements, the methods ancient astronomers had applied to the movements of the skies!

The dessert arrived and was eaten without delay. Everyone was eager to go outside and enjoy the rest of the afternoon looking at the landscape, such as the river Sado, the rice fields and the trees typical of that area. I proposed the return journey be made via the road linking Alcácer do Sal to Tróia, south to the Sado, to cross its estuary on one of the ferries that connect the Tróia peninsula to Setúbal. It's always a pleasant way to enjoy closely the Sado estuary with the Arrábida mountain range dominating it. My offer was accepted and there we went.

This time the conversation began as soon as the car started moving. Amadeus was the first one to speak.

- I think we understood what Galileo's main role was, and here this word has its full meaning, during the scientific revolution of the 17^{th} century. But the way those ideas imposed themselves and finally won constitutes a process that definitely wasn't peaceful. I know Galileo's last book, the one you told us about in which he presented his first results of application of his new scientific method, the first results of his new epistemology, were published in Holland by Elsevier publishing and not in Italy as were all his previous ones.

- That pronounced a "token passing" to the centre of Europe known as having advanced new ideas – agreed Fabrus. – The intellectual terrorism carried out over Galileo didn't stop him writing this last piece already after his condemnation and humiliation.

The action led by the Catholic Church through its institutions in order to stop the advance of new ideas, ended up not being very effective. During the 30's, Descartes wrote the *Discourse on the Method* and developed a whole system of Physics capable of replacing the Aristotle Physics, although it showed a radical reasoning that in our days we would consider naïve.

His famous collision laws are an example of that. Only the first one was correct. When confronted with that difficulty, his answer was that those laws were valid for perfectly hard bodies, bodies that didn't actually exist!

In a certain way, we can consider that Descartes made a radical reading of what Galileo had initiated. He tried to create laws for a world that only existed in his imagination. Galileo didn't make that mistake.

He always looked for the support of experience for his ideas. He knew his method needed to simplify that world, but that simplification had as limits the need to correspond, within an acceptable approximation, to observations and experiments. That's the reason why, while fighting Aristotle's Physics, he tried to show his ideas and results achieved through them were less distant from the observations than from Aristotle's ideas.

- Can you give us some examples? – asked Lucius.

- I will only give you one – answered Argus. – Viviani, Galileo's disciple authorized by the Inquisition to accompany him during his last years of life, tells in a biography he wrote about Galileo of an experiment the latter made when he was still professor at the University of Pisa, letting two bodies of different weights fall from the top of the Pisa Tower in order to prove, confronting the Aristotle position, they would reach the ground at the same time.

Today, no one believes that Galileo performed this experience with the aim to prove what Viviani states. Galileo knew both weights wouldn't reach the ground at the same time! Even if the shape of both weights was exactly the same, and if one of them was made of lead, heavier, and the other one made of iron, lighter, Galileo knew the piece of lead would hit the ground before the piece of iron. Galileo knew that both bodies would only hit the ground at the same time if air friction didn't exist. We can all perform a very simple experience that slightly exaggerates the effect of the air friction over two bodies that present a surface similar to the air friction while falling.

Let's take an A4 sheet notebook and separate one of those sheets. Let's grab the notebook with the right hand and the sheet with the left hand, both at the same height. If we drop them at the same time no one doubts that the notebook reaches the ground much sooner than the sheet.

Apparently, Aristotle's Physics described this phenomenon with a wider approximation. Galileo intended now to explain the movement, admitting the air didn't exist, a practical impossibility. Galileo had to follow a strategy that recurred once more to induction. For that, he would choose two bodies much heavier than the notebook and the paper sheet. Like two metal spheres so that the Earth's attraction effect would override in a more evident way the resistance effect the air exerted over the two spheres. The time period between the arrival of the lead sphere to the ground and the arrival of the iron sphere was now shorter than the time period between the arrival of the notebook and the paper sheet. He could also consider two metallic and pointy objects (such as two totally metallic spears) so that the time period between the arrival of the lead spear to the ground and the arrival of an iron spear, dropped at the same time, was even shorter. Galileo was mining the Aristotle statement that the speed of a heavier body falling was bigger than the speed of a lighter body.

- It's a kind of guerrilla war – dared Amadeus to say.

- I don't agree – answered Argus. – Galileo engaged into a war on all fronts. He mined Aristotle's Physics showing his epistemology and the resulting laws were much more in accordance with the experience data if we looked at them from the position he wanted us to. But he also resorted to purely logical arguments.

A logical argument was used by Galileo in order to equally fight Aristotle's statement that heavier bodies fell down at a faster speed than less heavier bodies.

Let's imagine two bricks that fall separately and with equal speed. Let's also imagine that at a determined instant during the fall they unite. Would that be the reason why both bricks would start falling faster for constituting a set, a heavier body than either of them considered in an isolated way? The answer was obviously no.

Another argument of that same type came from the situation by which a heavier body and a lighter body were dropped from the same height. If Aristotle was right, the heavier body would fall faster than the lighter body. If now both bodies were dropped at the same time, but bonded to each other, one might ask one question. Will the lighter body slow down the heavier body within its fall?

If that was so, we would reach the absurd: a heavier body, i.e. a set of two bodies linked to each other, would fall at a slower speed than the hevier body, being the heavier body considered in an isolated way.

- Interesting arguments – added Lucius. – They showed that Aristotle’s Physics was auto-contradictory, meaning it wasn't consistent.

Argus concluded:

- Galileo was able to prove it, but it took two thousand years, from Aristotle to Galileo, for that to become evident!

- The conceptual frames in which we move is what most difficultly changes – intervened Amadeus. – And this one, in particular, had been silted up during all that time leading men to identify the world with Aristotle’s ideas.

- That wasn't the last time it happened during the history – added Argus.

- What do you mean by that? – asked Lucius.

- It’s a long story. Let’s leave for some other time, it’s already late and we’re arriving in Lisbon.

SECOND JOURNEY

During the last journey, Lucius, excited with the conversation took the initiative to schedule the next meeting.

One of Amadeus's friends had a bookshop in Bairro Alto where debates were held at night time regarding all sorts of themes.

The owners were a couple of Philosophy teachers who, in a daring move, committed themselves to create a location where debates could take place, the kind of debates that don't cross over the barriers of the universities and that don't occur there too often. The *Eternal Return* was a quiet but nice place located at no 42 Rua de S. Boaventura. Amadeus was responsible for the choice of this location, since he was a regular of these debates. The meeting would be held on a Wednesday. We all got there almost at the same time. At 9 p.m. we were all already seated at the same table. The room had book shelves in several points, six tables, a piano and a counter at the end where one could get some drinks.

- During our last conversation I've learned how modern science had begun – I started. – What are we going to talk about today?

- I think we shall not continue talking about Physics history from the point where we were until today! Or do you want to do that, Liberius? – questioned Argus.

- Maybe we could all learn something – I said.

- Definitely! By knowing Physics' history we can better understand the problems that arose and those we face nowadays – replied Fabrus.

- Of course! – added Argus. – I totally agree with Fabrus. But I would like to reflect upon the main problems that Physics presently faces. If we talk about Physics' History it will have to be in a succinct way, only tackling the big steps and not the small ones or the details, as important as they might have been for that time. It will always be a History of Physics' ideas.

No one disagreed. It was Lucius who tried to initiate the debate.

- I think we all understood, during our first conversation, the meaning of the 17th century scientific revolution. Galileo showed the way. He only committed to describe mathematically the local movement. Modern Physics has become more modest: it stopped intending to describe Nature in a global form.

Amadeus decided to interrupt:

- But did Science give up trying to understand Nature globally? Is Physics, which stems from the Greek word *physis*, meaning Nature, giving up its initial purpose?

Argus intervened:

- The 17th century scientific revolution defined the path to be followed, and the method to be used. The path followed until then was worn out, ineffective. The proposal, such as everything that's innovative, was quite daring. Galileo managed to obtain the first mathematical laws that describe the local movement. As I've pointed out, only the local movement was being handled. And not the broad sense movement given by the Greeks, the change, the *Devir*[3]. Galilee Physics was much less ambitious

[3] NT: ***Devir*** is a philosophical concept to qualify continuous change and which implies that all things are perennial. It can be literally translated as *eternal change*, in the words of Heraclitus.

than the Aristotle Physics but, regardless of that minor ambition, amongst the *Discorsi…* of Galileo, it was published in 1638, and Newton's Mathematical Principles of Natural Philosophy, was published between 1684 and 1687, only half a century divides them, the new method was definitely much more promising.

- Promising to describe the local movement? – asked Lucius.

- Of course! – answered Argus. – That was Galileo's study purpose. That was the cognitive gain of the scientific revolution within the Physics' domain. The proposal to reduce the object of study to the local movement looked now apparently correct. Although, as we well know, that wasn't immediately accepted by the cultured Europe of that time, because Newton's Physics only began to be generally accepted from the 30's of the 18th century. But it was an inevitable acceptance. His capacity of describing with great approximation the phenomena related with the local movement was huge.

- But if that was so, why did it take so long between the introduction of the new scientific method and the acceptance of its application results? – asked Lucius.

Argus smiled and answered:

- That question makes much sense. But only to someone who doesn't deeply understand what science is and how it evolves, can be surprised with the time it took until the acceptance of the consequences of the new method.

Scientific activity is mostly subject to the same constraints as other human activities. The masters had learnt Cartesian Physics and that was the one taught in universities. The resistance is gigantic when one tries to abandon a theory and replace it with another that rejects the ontology, meaning the metaphysics of the old theory which supports itself. And this happens even if the new theory proves to be more capable of describing phenomena.

There were philosophical reasons not to accept Newton's gravitation. By unifying the earthly Physics with celestial Physics Galileo forced the same causes to produce the same effects. But Newton's gravitation raised an ontological problem. And what was that?

Even those who accepted the new method didn't peacefully accept the existence of a force between, for example, the Sun and the Earth. We know that a rock into a sling describes a movement almost circular. But that is so because there is something that holds it to the centre of that trajectory, meaning the cable that keeps the rock linked with the hand that causes the movement. But where was the "cable" that linked the Earth to the Sun? What is that forces support?

It's in that context that Newton's famous sentence arises "*hipotesis non figo*", meaning "I don't create hypothesis". The mathematical expression for the gravitational force, as we all know, is proportional to the product of the mass of the bodies that we are considering and to the inverse of the square of the distance that separates them, allowed calculating with great precision for the Earth's trajectory around the Sun or Mars trajectory around the Sun, etc.

As a pragmatic would say, it worked.

This was Newton's answer to the objections made by the Cartesians and Leibniz himself regarding the general acceptance of that law.

- Leibniz didn't accept it? – asked Amadeus.

Argus continued: - He didn't accept Newton's gravitation because he didn't understand its cause. Which was the physical support for that action to take place? Leibniz invoked the principle of sufficient reason, what we would call today the principle of casualty in order not to adhere enthusiastically to Newton's ideas regarding the gravitational realm.

- You mentioned the Cartesians, but you didn't say where you stand!
- added Lucius.

- You're right – answered Argus. – It would be important to talk about Cartesian Physics because that's what replaced Aristotle's' Physics in universities, but I won't take much time with it.

It was a Physics founded in metaphysics able of replacing the Aristotle theory that we talked about. II will not detain myself on the details of that metaphysics. I will just say that it was founded in the conception of a Universe completely filled by matter, identifying the space with matter itself, meaning there was no space without matter or matter that didn't occupy space. There would be several types of matter, such as "subtle matter" that would occupy all gaps and that would guarantee the fulfilment of all space, "celestial matter" would take on a spherical form and the "rougher matter" that would constitute planets.

From this ontology it would be possible to assume that planets would circulate around the Sun, being dragged by a whirlwind of "celestial matter" centred in the Sun. As a matter of fact, it considered all stars as centres of similar whirlwinds. The whirlwind around the Sun would be the cause for planets to move around it and that would be the interaction support between the Sun and the planets that could be described by Newton's gravitational force. However, that force expression would have to be deducted from another metaphysic, i.e. from another vision of the world.

- It's an interesting idea – interrupted Amadeus.

- Maybe, but neither himself nor his followers managed to deduct Newton's gravitational law from such a conception of the world. And yet, it was this Physics that was taught in the universities for many decades.

- How was that possible? – questioned Lucius.

Argus replied:

- Descartes was a Philosopher that left an indelible mark in European thought during the 17th century. Leaving an Aristotelic conception of the world implied the search of another one with whom it could be equivalent. One conception that accepted the Copernican system. The Cartesian ontology soon presented itself as the most complete and coherent one. And that, together with the prestige of a thinker like Descartes, was the reason why its metaphysic and physics could have been integrated within the universities' teachings. And this, regardless of the fact it was unable to quantify the way the phenomena was related with local movement.

- Nowadays that would be impossible to do! - defended Lucius.

Argus continued:

- Not under the terms how it happened in the beginning of the 17th century and in the beginning of the 18th century. But in the 18th century, after the acceptance of Newton's Physics, something similar happened in another Physics domain. Newton's mechanics and gravitation managed to describe within a reasonable approximation the movements observed at the surface of the Earth and within the solar system. However, Newton's optics that were also accepted during this century under the protective shadow of mechanics and gravitation, revealed difficulties in describing some luminous phenomena.

If one had looked to Huygens optics more carefully, if one had taken it more seriously, they would have observed that it described almost everything about Newton's optics and some more phenomena that Newton's optics didn't manage to describe. It only failed to describe a phenomenon easily described by Newton's optics: the shadow phenomena.

- Maybe there were not neither experimental tools nor theoretical tools, at that time, allowing deciding between those theories – suggested Fabrus.

- That’s not totally true – answered Argus. – With the means of the time one could have easily verified the inaccuracy in Newton's statements regarding the phenomenon of double refraction. On the other hand, Huygens' theory described in a correct and quantifiable way the behaviour of the so called extraordinary ray when incident in a parallel or perpendicular way the main symmetry plan of the birefringent crystal.

- What crystal is that? – asked Lucius.

- It’s a simple calcite crystal with the form of a rhombohedron. If you place a crystal of this type over a sheet with a written text you can see the lines of that text duplicated, meaning that each light ray falling upon it results in two refracted rays with different properties – augmented Argus.

The first one is called an ordinary ray because it behaves like a normal refracted ray over a surface of separation between two different optically mediums, such as for example, air and water.

The second one is called an extraordinary ray because it behaves in a different way from the ordinary ray.

Of course Huygens managed to describe the ordinary refraction phenomenon with its conception of light, but the most interesting factor was his capacity to describe the behaviour of an extraordinary ray. He managed to describe the behaviour of the latter explaining it in a way that could be peacefully integrated within the general picture, in ontology, in which its optics was based upon.

- And what’s that picture you’re talking about? – questioned Lucius.

This time it was Fabrus who answered:

- Huygens admitted that light would be a disturbance of a medium. A disturbance that would propagate into that medium in a similar way to that of a liquid’s surface waves.

However, I should add that there was a difference between Huygens’ luminous waves and sea waves. As we know, these oscillate in a perpendicular direction to the propagation direction. According to Huygens, luminous waves would oscillate in a direction coinciding with the propagation direction.

You want an image I could state the oscillations of a very large set of juxtapositioned springs and with a body with mass in the connection points. A small movement of one of the masses into a collinear direction on the axle of a spring set would cause an oscillation along the axle. These waves are called longitudinal waves. Huygens admitted that, beyond a spherical wave, such as the case of the normal refraction, there would exist a simultaneous ellipsoidal wave inside the crystal. Such as Argus stated, this assumption managed to describe in a quantitative way the form under which the extraordinary ray would behave inside the crystal when incident parallel or perpendicular to the main symmetry plan of the crystal. When incident on other directions, this description didn’t conflict with what was being observed, regardless of the fact it didn’t manage to describe it quantitatively.

- But wasn’t that an important argument not to accept it? – asked Lucius.

- It would be if an alternative theory could have explained it – replied Argus, continuing: - That wasn’t the case. The rule that Newton introduced to describe the behaviour of the extraordinary ray was incorrect and that mistake could have been easily checked with the means available at the time.

This is a good example of what Lakatos called the negative heuristic of a scientific research program associated to a determined metaphysics and consequently to a determined vision of the world.

Naturally, the Newtonians of the 18th century preferred to privilege phenomena more docile to the integration within the Newtonian world conception, within the domain of mechanics and gravitation: what Lakatos called the positive heuristic of a scientific program. They were less eager to carefully analyse the phenomena in which the metaphysical frame they moved in showed less capacity to describe.

- But wasn't the study of light a theme far too important to be neglected like that? - asked Amadeus.

- Of course it's an important theme, besides being associated to eyesight, a sense we all privilege. But in the 18th century the success of Newton's mechanics and gravitation outshone the study of luminous phenomena. That was the main reason why the *Optiks* of Newton, written in 1704, made us forget the *Traité de la Lumière* of Huygens, published in 1690. It remained in the shadows for more than one hundred years.

- You mean that no one looked to refute Newton's optics for more than one hundred years? – asked Lucius, surprised.

Argus smiled and answered:

- In reality, in spite of the less favourable environment, there were those who wanted to undermine the credibility of Newton's optics during the 18th century. I will talk about one case.

As many of you already know, Newton studied the behaviour of the light propagating in prisms. A prism being a glass parallelepiped with a triangular basis. When the sunlight shines upon one of its side faces it's decomposed into the colours of the rainbow while crossing it. Therefore, a lens whose section can be close to a succession of prisms, causes a similar effect. Newton got to the conclusion that it would be impossible to build a lens that didn't suffer from this type of problem. Meaning it was impossible to build an achromatic lens. A lens that wouldn't suffer from the "disease" of producing an image with the colours of the rainbow, the so called chromatic aberration.

However, Euler noticed there were natural lenses, our eyes, that behaved like achromatic lenses. As a matter of fact, our eyes don't decompose sunlight into several colours of the rainbow. This was the beginning of the heuristic process that led Euler to demonstrate, during the 40's of the 18th century, the possibility to build achromatic artificial lenses.

He proved that, by associating two transparent optical mediums with different refraction indexes, we could build achromatic lenses. This result allowed, shortly after, for Dollond, a British lens manufacturer, to produce the first achromatic lens.

Here we have an excellent example of a theoretical constraint to the instrumental development. For half a century no one dared to build an achromatic lens because the theory forbade one to do so! I should add that Euler was a Leibnizian. And as such he didn't accept the metaphysics that supported all of Newton's Physics. And that was the reason why he was impelled to denounce this error of Newton's optics. It's necessary to remember that Euler didn't manage to create a theory of light based upon Huygens' wave conception. But this episode highlights the fact that a theory can erase constraints to the development of new instruments.

- Is it possible that still today something similar is happening? – asked Lucius.

- Everything points to an affirmative answer – said Argus. – However, it's not possible to say it for sure. Within the scientific literature of Physics, in magazine articles and books written in the past 20 years, there are many proposals of experiences that are based upon theories alternative to the ones commonly accepted.

Strangely enough, these proposals did not lead to the performance of those experiences. Maybe something is happening similar to what happened in the 18th century. Presently, not among the Newton and Huygens' conceptions, but among Bohr's indeterministic quantum mechanics and the alternative more general nonlinear causal quantum physics, inspired on de Broglie´s ideas.

These situations are recurrent. I remind you that other cases existed, before and after the conflict between Newton and Huygens on the nature of light.

Let's not forget Aristarco that already in the 3rd century before Christ proposed a heliocentric model like the one Copernicus proposed in the 16th century.

In this case it wasn't only one hundred years, but around 1,900 years! Of course, in this case, human societies had a rough life between the Hellenistic period and the end of the so called Renaissance, and only among that cultural "soup" were there conditions that allowed this proposal to develop. And we all know how new science rapidly allowed the creation of new instruments such as the best clocks, and here we need to mention Huygens' work.

- Are you highlighting the fact that physical theories allowed the creation of new instruments? - asked Amadeus.

- You're right. I'm doing it because I consider the capacity of building new instruments until then inconceivable, the last evidence of what a theory must overcome in order to be accepted as a physical theory – answered Argus, continuing: - Without falling into an immediate or utilitarian pragmatic position, I think this is the last criterion that a theory must overcome. There are others, of course!

The first criterion is to agree with the phenomena one intends to describe, always within certain approximation. But this criterion doesn't get rid of theories and mathematical descriptions that are in accordance with the phenomena observed, with allowed precision in a determined historical period and that, we know today, may not be more than a simple formal construction without the latest capacity to extend our capability to act upon the world.

I am talking, for example, about astronomic models that used to express themselves by means of geometric constructions such as the deferent and epicycles, whom with the ancients intended to describe the movements of the stars in the skies - and what an achievement that was!

What we manage to do these days by launching satellites into space or probes into other planets is something those models couldn't even conceive.

With Newton's gravitation and other physical theories that, in the meantime, were created, we were able to do so.

The second acceptance criterion of a physical theory is the ability to predict new phenomena. I can give you a famous example of Physics history: the so called Poisson luminous point.

This event is part of the conflict between both conceptions of light already mentioned, i.e. Newtonian corpuscular conception and Huygens wave conception.

In the beginning of the 19th century, period during which one still savoured the successes of Newton's gravitation and where important personalities stood out such as Laplace, Lagrange, Monge and Poisson, amongst many others defenders of Newton's conceptions, Augustin Fresnel, a French bridge and pavement engineer has created a light wave theory that was able to describe all luminous phenomena known then.

Already in 1800, an English medical doctor, Thomas Young showed that when the light originating from a unique luminous source passed between two small holes and with little distance between each of them would produce on a target placed after what we call an interference image, such as we see in the drawing - and he makes the drawing:

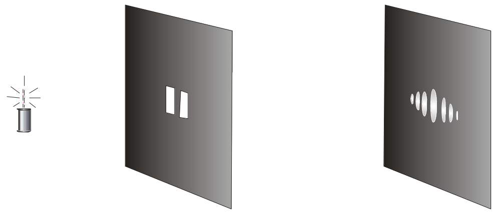


Fig. J2.1 – Young experiment.

A corpuscular conception of the light, meaning a conception for which the light would be composed by corpuscles that move in a straight line from the emitting source would have much more difficulty in explaining this experimental result.

This phenomenon is easily explained admitting that the light is made of waves. Fresnel theory was able to explain it perfectly.

The light source emits a wave that by arriving at the screen with two holes originates two waves. These two waves shall propagate and overlap. It's exactly this superposition that explains the interferential pattern we can see at the target. We say both waves interfere with each other. On the points where both waves' crests mix, a bigger wave is created originating a much more lighted area. It means that the joint action of both waves is reinforced. In the areas in which a wave's crest overlaps with the downcrest, they end up annulling each other thus originating the absence of light.

In this case, the wave conception of the light enables the possibility of explaining the appearance of shadowed areas alternated with lighted areas. On the contrary, the corpuscular conception cannot explain the appearance of shadowed areas.

- I think I understand – intervened Amadeus. – But you were talking about the capacity that theories have to predict new phenomena and you've mentioned, and I'm not sure I'm saying it right, Poisson's point.

- Yes, you're right - commented Argus. - I wandered off the subject for a bit, but it was necessary.

As I told you, Poisson was a true Newtonian and he didn't easily accept a wave conception of light. Another characteristic that Poisson had was of being an excellent mathematician, allowing him to perform calculations with great accuracy. He devised the following experiment.

Let's imagine a point like source. A black box with one light inside and a small hole on one of its sides is a good proximity of such a source. Next, one places a circular object in front of that hole in order not to stay too far from the vertical to that circular object that passes along its centre.

By using the light wave theory of Fresnel, Poisson tries to predict what would be the shadow's form the circular object would project upon a wall placed behind it. Let's not forget that it was their very shadow phenomena the huge argument presented against Huygens' light wave theory about one century before.

By adopting Fresnel's theory, Poisson verified that there should be a luminous point exactly upon the centre of that shadow such as one can see in this sketch - and he – draws Fig. J2.2:

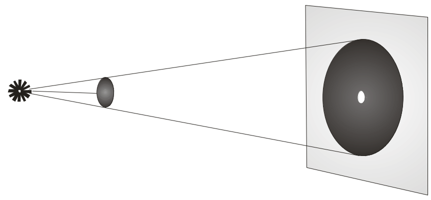


Fig. J2.2 - Poisson's point

He presented this conclusion as a refutation to Fresnel’s theory.

As it would be natural, since we are talking about a scientific statement, it would be necessary to experimentally confirm if that luminous point existed or not at the centre of the shadow.

The experiment was made accordingly and the luminous point appeared at the centre of the shadow as the wave theory predicted!

This is a case by which a theory’s prediction, unsuspected until then, is confirmed. And this is the second validation criterion for a scientific theory, that is, the second criterion which allows us to conclude that the theory, at the scale we're describing reality, constitutes a good approximation of that same reality.

But that criterion still has to protect itself against a risk. We know it was possible to predict Moon eclipses before Newton's mechanics and gravitation appeared. And we also know that mathematical models that served as support to that phenomenon prediction cannot be considered theories due to the fact that they didn’t verify the last validation criterion of a scientific theory. With those models we couldn’t build what we build presently with the physical theories we have.

- Are you saying that the ability of a theory allowing us to build new instruments is, in an ultimate analysis, the last validation criteria of that theory? - asked Lucius.

- Exactly – said Argus. – I think that’s the last and most decisive validation criterion of a physical theory. The possibility that allows us to build new instruments, therefore increasing our action ability in the world.

This criterion shows the existence of a major relationship between the world and what we think of it, between the world and our theories.

Of course we need to emphasize that it always refers to the scale by which we are describing this world. The world is far more complex than the theories we painfully build. The relation between our theories and what they intend to describe is always an analogy relationship and never an identity relationship.

It would be good if that was clear to all, including many scientists, so that their attitude towards science would be wiser than it frequently is.

The most paradigmatic historical example of this attitude was of the Newtonians of the 18th century when they stated there was just one world and that Newton had discovered the laws to that world. They believed Newton only left to his descendents the task to add decimals to the precision with which we could describe this world.

Time has proven how wrong they were. However, Newton's mechanics and gravitation continue today being useful to describe the world at a certain scale. At that same scale we were allowed to increase our ability of action in the world and that's the reason why we use it today.

When we send a satellite into space, we use Newton’s mechanics to calculate its trajectories. But we also know now the world is far more complex than Newton’s laws made us suspect. When passing to the atoms’ scale, Newtown’s mechanics and gravitation stop verifying the first criterion I've mentioned - its capacity to describe the observed phenomena.

- Are you generalizing that criterion to all theories created so far? - asked Lucius.

- At least it should be generally applied to physical theories - answered Argus, adding:

- All well established theories in physics inevitably do verify that criterion.

- Can you refer some of them? – asked Lucius.

- I will point out three of them, the ones that really matter for what I'm about to tell you - answered Argus. - First, Newton's mechanics and gravitation that I already talked about; second, the electromagnetic field theory and third, quantum mechanics.

- Did all those theories respect those criteria? - asked Lucius.

- These three theories respected all criteria that I mentioned before and all of them did overcome the last criterion with success - increasing our action ability in the world - enlightened Argus.

- Is there any physical theory that didn't overcome all those criteria? – queried Lucius.

- If they didn't overcome all those criteria they couldn't be considered physical theories – explained Argus. – At most they could be considered as physical theory projects, associated to scientific research programs.

- Are you defending that one shouldn't continue to investigate more within those projects' frame? – asked a stunned Lucius.

- That's not what I said. On the contrary! – answered Argus, explaining: - I think all theories should have a "gestation" period, this criterion shouldn't be imposed at first in order to prevent its natural development. Not even the first criterion I referred to should be imposed in the beginning.

- Hold on! Are you saying a certain theory should be able to subsist, regardless that its consequences are not in accordance with the results of the experiences or observations? – asked Lucius, astonished.

- Of course! – answered Argus. – I already mentioned to you one case where that happened. Do you remember when Copernicus proposed the heliocentric model for the Cosmos, such as, previously to him, Aristarchus did within the greek-hellenistic period, the big scientific argument against that proposal was the non-observation of the stars' parallax.

As we know, only in the beginning of the 19th century did one manage to observe that effect produced by the Earth's movement around the Sun. But then everyone already knew the Earth was moving around the Sun. The great majority of astronomers of the 16th century and beginning of the 17th century didn't accept the Copernican model and one of the reasons for that attitude was exactly the non-observation of the stars' parallax.

This is a classic case, already well studied, that enlightens what I was saying. I could point out another case, also already mentioned. When Huygens proposed a wave theory for the light, one of the arguments due to which it wasn't accepted was its incapacity to explain the shadow phenomenon.

Apparently, a corpuscular conception of the light managed to do that with little difficulty. We know this constitutes a rough simplification of what's been observed. The surface of the separation between the shadow area and the lighted area is not that clear. Looking at it more carefully, one would observe a succession of bright and dark areas that would indicate the phenomenon couldn't be that easily explained such as a corpuscular theory might suppose at first sight.

As I already told you, the wave light theory proved to be more capable to describe all luminous phenomena about one century after. Here's another case that highlights the dangers of a rushed judgement of theories. It's not fair for one to demand from an emerging theory, in this case the light wave theory, a total concordance with the phenomena it intends to describe.

- Are you saying we should support all theories that come along?! - asked Lucius, surprised.

- All theories that assume they have to try to agree with the experimental results should be supported. We should support them, but with good sense - said Argus.

- What do you mean by that? – asked Lucius once more.

- I mean we cannot support in an exaggerated way, either financially or in terms of human resources, projects of theories that are so because they haven’t managed to prove themselves capable of increasing our capacity of action in the world. Projects of theories of which we can't foresee the possibility of creating new instruments based upon the theories those projects intend to arrive at. Physics history during the second half of the 20th century give us clear examples of what I'm saying - replied Argus.

- Be more explicit – asked Lucius, curious.

- The instrumentalism associated to the thought of John Dewey must be transformed in the last validation criterion of a scientific theory. Integrated in a realistic conception is of great importance to denounce what has been the theoretical Physics during the second half of the 20th century and in the beginning of the 21st century - answered Argus, adding:

- With this I mean that the gigantic investment, either financial or with the lives of intelligent people made in institutions like CERN, wasn't useful to the creation of theories that managed to overcome this last criterion that I name as the effectiveness criterion. The criterion that proves theories are capable to increase our action capacity in the world. As I said, this criterion is the last proof of existence of some relationship between the world and what we think about it.

This is an ontological argument that inevitably distances it from a pragmatic attitude such as Dewey’s. Besides that, I think that our ability to painfully understand what surrounds us, inevitably reflects the world's characteristics, in accordance with a secular and realistic position that assumes we're something emerging from the world in which we are part of.

When looking for the Truth, we aren't recalling a Truth we could access in a previous existence, such as Plato stated; we are pointing out characteristics also existent in ourselves. The Truth is inside us, because we are and act in accordance with the same laws. This is the way I understand Kant’s "Copernican revolution" – stated Argus.

- That's a materialistic position! - intervened Amadeus.

- If you want it, but I do not like the term “materialism” nor the term “matter”. The word matter is too polluted for us to use it without any care in the world – said Argus.

Matter, such as we see it today, is far more complex than19th century man could admit. Quantum physics proves it. Niels Bohr Philosophy teacher, Harald Hoffding, said if we don’t want life and thought itself to have born from a divine touch we must find something similar to the behaviour of thought itself within matter's behaviour. It’s a very clever statement and with a profound meaning. This would imply that what is generally called matter already had the characteristics that led to the appearance of life and thought within itself – the ability to reflect upon oneself.

- Does that have anything to do with Bohr's quantum mechanics? - asked Lucius.

- Very little. To Bohr it was necessary to prove the difficulties to access knowledge. To Bohr, it would never be possible to know if those difficulties resided within the characteristics of the matter itself, let’s call it this lacking a better name for it, or within our own ability to understand. To Bohr it was necessary to prove the limits of our ability to understand the world in a rational way and that's what the principle of complementarity tries to express.

- You’re mentioned that principle several times – interrupted Amadeus. – That theme interests me. When can we finally talk about it?

- Patience - asked Argus. - I would like to talk first about other themes in order to prepare the way to talk about that principle.

- Oh Argus, you were just talking about the huge investment made and still being made in institutions like CERN. In your opinion, such investment wouldn't have contributed for theories to be developed that successfully overcome all validation criteria of a physical theory - interrupted Lucius.

- That was at least the goal of that huge investment. But we must admit with small results - added Argus.

- But something similar happened between the introduction of Faraday's idea about the physical field, between 1815 and 1821, the appearance of Maxwell's electromagnetic field theory, between 1887 and 1888, that was a forecast of Maxwell's theory - intervened Fabrus.

- I can’t deny the facts you’ve just referred to – agreed Argus.

- But in order to compare the period you've just mentioned and the second half of the 20th century within Physics domain, it's necessary to compare the financial and intelligent people's investment in those two periods. If we follow that road, productivity in science is clearly unfavourable during the second half of the 20th century. And it can't be used as an argument that today it is necessary for more money and bigger teams in order to go forward in the Physics domain. It was never easy to advance in terms of knowledge, whatever the time being considered. We can't say that presently it is more difficult than what has been until now. That would reveal an inadmissible disrespect towards our ancestors, allowing the future generations to say that advancement today would have been easier than it will be in the future. Presently, one invests in science much more than in the past, but the results are scarce. We are all told that investment is necessary for Physics to evolve. We are then obliged to ask: if that's so, why doesn't it evolve? Theories' projects created in research centres such as CERN didn't manage, don't manage, to overcome all validation criteria of a theory, namely the last one I stated, which has the ability to build tools that increase our action capacity in the world from those same theories. It’s not just about promoting new instruments based upon previous theories necessary, that one can build new instruments based upon the theories we’re trying to develop. After that step, we can then state that the logic associated to those research programs, the positive heuristic mentioned by Lakatos, imposes that investment. The question that I present here is: Is it really necessary to go down that road? Wouldn't it be more useful to look at phenomena in another way? Wouldn't it be preferable, given the more than evident crisis, such as Koyré said, to meditate again upon the grounds of what we’re doing?

- But are there alternatives? – asked Lucius.

- Of course! – answered Argus immediately. – It’s unacceptable to make disappear other research programs within Physics that come from different assumptions. Programs that come from other forms of metaphysics. It’s impossible to build on Physics without a previous metaphysic. I’ll give an example. We can state the electron is still today a particle without structure for these research programs within the domain of Physics developed in research centres such as CERN. There are concurrent research programs that propose experiments with the goal to prove that a photon has an inner complex structure. Furthermore, experiments that can be performed at a very low cost.

If there is an elementary particle in Physics within the present state of our knowledge, that particle is the photon. The electron, a point without structure for research programs of institutions such as CERN, is for other concurrent research programs a gigantic particle regarding a photon.

- But nowadays great investments are necessary to be able to attain the height energies necessary to perform experiments that try to evolve in the study on the structure of matter - insisted Fabrus.

- In accordance with the positive Heuristic that research programs follow that's the outcome - replied Argus. - Many times, and science history is prodigal in giving us examples of that, it becomes necessary to follow another way, another research program that allows us to move forward in a more effective way. Often it becomes necessary to change the vision of the world, ontology, so that difficulties that arise to the intelligibility of this world may collapse, at least provisionally.

Argus looked at us and continued:

- I want to call your attention to a danger emerging when investments in scientific research reach the present values. These investments are linked to interests that have nothing to do with scientific goals. Science last goal is the search for the Truth, even recognizing that during that search we're just climbing steps that correspond to a phenomena superior intelligibility state, that isn't the Truth!

It's necessary to remember there is a whole industry that produces the instruments, whose functioning is based upon previous theories well founded and not on theories' projects in question. This industry defends, as is natural, its own interests. These goals may not coincide with the goal of science. In this there is a danger of the same companies promoting the research programs that give them more proceeds. It's necessary to be very much aware of that danger.

Another danger is confusion, a very common one, existent in many minds, between technological and scientific research. The huge technological progress that happened during all of the 20th century and in the beginning of the 21st century cannot be confused with the progress of science, at least within the domain of Physics. They are two different things. Although I defend the possibility to create new instruments as is the last validation criterion of a scientific theory, it's not fair to identify science and technology.

When we hear today, without protesting, that industrial activity should be linked to the scientific research, we're making a big mistake. They should say industrial activity should be linked to technological research. Superior technological teaching schools should be closer to the industry needs. They could only gain with it. But that doesn't mean we should transform these schools into industrial companies' departments. There are technological inventions that were achieved without any company's financing. Ingenious men, the real engineers, have achieved to manifest without the financing of any company. By majority of reason, by everything I've said, it's unthinkable to try to transform superior (not technological) scientific schools into extensions of the industrial activity.

We can't confuse scientific research with technological research. The latter is presently, inevitably, always linked to the first one. Technological research wouldn't exist today without scientific research happening first. How many scientific revolutions will be occurring in the future? No one can predict it with safety. No one can surely predict how our life in society will be in hundred years. Nor in fifty! Scientific development can lead us to the usage of tools that are unimaginable today.

For all of this, science must be able to develop without bowing before any established interest: political, religious or business. Science is an activity that doesn't survive without freedom. A freedom that needs to respect general society’s ethical principles (always developing) is where scientists belong. Freedom allowing for the undertaking of theories’ projects. I highlight again that it's necessary to give an "incubation" period to those theories' projects, a period of great freedom for them to develop, but with wise investments aware of the dangers I mentioned before. But this cannot make us forget we should always look towards scientific activity taking into account the validation criteria I've been defending, meaning we should only consider established theories the ones well founded, the ones that have managed to increase our capacity of action in the world. This attitude would avoid much confusion existing today within the domain of Physics.

- Are you saying that big investments are only justifiable when we’re doing technological research? – asked Lucius, astonished.

- No – replied Argus. – I’m just saying that investments in science must be made with great prudence. It was important to build the spatial telescope Hubble. It’s important to build new and more powerful telescopes to increase our information about the Universe. It’s important to know better what surrounds us, even if it’s far away. It's also important to know what happens in empirical terms within quantum particles' divisions, which is what happens in the big particle' accelerators, in spite of the theories' projects that are built in order to handle phenomena observed as being too fragile in order to be taken seriously. But, I repeat: the immense investment made, for example, in the so called particle Physics, in financial and intelligent manpower terms, has resulted in poverty-stricken theoretical results. None of the theories' projects tried to be built within this area of Physics, managed to overcome all validation criteria of a physical theory.

- Isn’t that a too radical statement when talking about poverty-stricken theoretical results? - questioned Lucius.

- It's not a radical statement - answered Argus. - It's an inevitable statement when looking to those theories’ projects. They don’t allow us to increase our capacity of action in the world in absolutely anything. When this happens, it's inevitable to look at them with a huge amount of suspicion. They have used great financial means with a profitability that doesn’t reach mediocrity itself. I'm not saying this, nor would it be coherent with what I said previously, to conclude these theories' projects should be stopped. We must only have a little more good sense. In theories' projects, which is what scientific research is all about, investment should be very prudent. In experimental Physics we should worry in checking the profitability of the installed and to be installed instrumentation, knowing that it's always expensive and that investment, in one way or another, always resort to the wealth produced by the citizens of a community. This individual effort requested from citizens must be respected and not used in a frivolous way. When Clinton failed the construction of a big particle accelerator in Texas it proved that concern. The investment necessary for its construction would be gigantic. It would be more expensive than the construction of the Channel Tunnel.

- Was it that expensive? – asked Lucius, surprised.

- To build a tunnel closed over itself almost 90 km long and with several meters deep is not cheap – answered Argus. – Besides that, it would be necessary to buy all the necessary instrumentation for particles to be accelerated along that tunnel and the necessary instrumentation to observe objects resulting from particles’ collisions accelerated in the meantime. It would be billions of dollars. One predicted a cost of 8,25 billion! And for what? To continue in an investigation where logic shows less than mediocre profitability? To pursue scientific research programs that cannot overcome the scientific theories' projects stage in spite of all this investment along dozens of years? You must agree it didn't, it doesn't make much sense.

- I never thought about that – admitted Lucius.

Argus continued: - I remind you once more that when a theory project is able to pass to a well founded theory, because it has managed to overcome all of the validation criteria as I referred to before, not even that theory keeps an identity relationship with Reality, but only an analogy relation. In a theory project one can't even guarantee the existence of a minimum reliable analogy. In a well founded theory we can have some trust within approximation between what we want to translate and the way we translate it. In a project theory we don't even have that.

- Translate what? – asked Lucius, surprised.

- I was thinking about Galileo's famous sentence that I already quoted before and I repeat again: "*Philosophy is written in that great book which ever lies before our eyes - I mean the universe - but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. This book is written in mathematical language, and the symbols are triangles, circles and other geometrical figures, without whose help it is humanly impossible to comprehend a single word of it, and without which one wanders in vain though a dark labyrinth*."

This image of the Universe as a book used by Galileo seems useful to make myself clear. Physics always tries to translate that great book Galileo calls the Universe into a language we understand. After Galileo that language has been the mathematical language, presently well more complex than the elementary geometry he referred to. Nowadays there are much more characters, but there is also a much more complex syntax and a semantics unique for that language. The most difficult part to learn of a language is its semantics: what's the meaning that a particular set of characters acquires when integrated in a certain context. Mathematics itself introduces its own semantics. But a physical theory while using a mathematical language must use another semantic that relates that language with the physical phenomena it intends to translate. It introduces new meanings, better yet, it introduces and reinterprets the symbols used in that language so that it may be used to describe the phenomena observed.

We can face a physical theory as the translation of a language constituted by the phenomena we observe, what Galileo called the book of the Universe, into another language in which characters, syntax (logical rules) and basic semantics used are characteristic of another language which is mathematics. In a translation, the final text in the downstream language never is exactly the same as the original text in the upstream language. The same happens in Physics, but in a far more dramatic way, because that translation is linked with a basic purpose of our own species which is to turn the world surrounding us more intelligible, not with the dilettante goal of erudition, but with the goal to increase our ability to survive as a species. This drama is not exclusive of Physics, but this is our subject and this is the domain of science that, in a systematic way, has looked to undertake that translation. However, that goal is never totally reached by the simple reason we are subject to the condition of translators. That's why I've asked for your attention to the relation between the world and what we think of it, our theories, which is never an identity relationship, but an analogy relationship. An analogy that can increasingly approach the identity without actually reaching it. A translation that can get semantically closer to the original text, without ever transforming itself into the original text, precisely because it is a translation.

- When you say the effectiveness criterion is the most rigorous one in terms of verifying a theory, you're really saying that translation should be more rigorous when respecting that criterion – intervened Lucius.

- That’s what I’ve been trying to defend – answered Argus, - and as it’s easy to conclude, this position has direct implications regarding scientific research policies. These policies manage the money that all citizens in a community grant to the scientific research by means of a certain Government. These citizens are entitled to obtain information regarding that investment profitability. They are entitled to know if the semantics used is the most correct one, if the assumptions constitute the theory's hard core and all others that, in a explicit or implicit way, gather around them in the attempt to increase their capacity to describe the observed phenomena, to constitute, I repeat, a semantics allowing to obtain a better balance between both "texts".

That’s why I question the so called scientific disclosure when it praises a certain theory. A theory is often presented as if it's not just a theory but THE THEORY. They fall, not naively now, into the same mistake as the Newtonians did in the 18th century when they believed that Newton had achieved the most rigorous description that one could ever achieve. A description of the reality itself, of the thing itself and not a description of the phenomenon. A theory is a translation of phenomena observed (the book that is the Universe for Galileo) into a new language - Mathematics. But that translation introduces a semantic by means of assumptions and definitions in which the theory is based upon. The maximum we can wisely state is that, at the scale we’re trying to describe the phenomena observed, that theory is an acceptable translation of phenomena observed for a mathematical description of those same phenomena if that translation – that theory – overcomes all validation criteria of a scientific theory.

- Is it not necessary to state that Kant also pointed out to the fundamental distinction between a phenomenon and the thing itself, meaning the noumenon? – asked Amadeus, looking to clear up a point that seemed less clear.

- You’re right, Amadeus - said Argus. - The thing itself would be, in this case, not the original text, but the thought of that text "author", if that author exists. Einstein said once to his disciple, Ernst Straus, he would like to know if God had had the freedom to make the world in another way. This is the “God”, here invoked by Einstein, I’m talking about when I say “author” of that text. Not the God of myths. Not the Book’s God. The text would be the phenomenon, since it’s what allows us to interact with the “thought” of who wrote it. But this text has one characteristic normal texts don’t have. It’s a text that allows us to ask questions in the attempt to get closer to its most profound meaning. That's what we do when we perform experiences. One experience is, ultimately, a question made to Nature. But it’s important to highlight that a question always needs two presuppositions: a conceptual basis that makes sense and a language in which we can formulate it. After Galileo, the language used has been the mathematical language with a syntax that evolves with that branch of science, and its own semantics that also evolves. Galileo was convinced that the God who had built the world would know mathematics; that by creating it, He did so according to mathematical laws. On the other hand, the conceptual basis varies from theory to theory, since it is exactly what I stated before when talking about semantics, and this semantics is indelibly linked to metaphysics over which a theory is built upon.

- Can you give an example? - asked Lucius.

- Yes – answered Argus. – Let’s consider the next simple mathematical equation:

$$\vec{x} = w \times \vec{y}$$

This equation has a certain syntax and its own basic semantics given by mathematics. We can say that the letter *w* represents a real number bigger than zero, meaning we can replace that symbol by any real number superior to zero. Letters *x* and *y* have an arrow on top that indicates they represent straight segments with a privileged way – oriented straight segments. They represent what we, in mathematics, call vectors. Up until now we've been talking about semantics. Let's now talk about syntax. The sign x tells us that vector $\vec{y}$ should be multiplied by the real number *w* in order to obtain another vector we call $\vec{x}$. That's what the equal sign means. In fact, it tells us that what's on its left hand side and on its right hand side is the same thing. Summing it up, given an oriented segment (vector) $\vec{y}$, we can obtain another oriented segment $\vec{x}$ with a different or equal length, if *w=1*, since we're multiplying the $\vec{y}$ vector by a real number *w*. That's what this mathematical equation tells us. Let's now change it slightly. Let's just change the letters we use. Instead of $\vec{x}$ lets use $\vec{f}$, instead of *w* let's use *m*, and instead of $\vec{y}$ let's use $\vec{a}$. The equation is, from a strictly mathematical point of view, exactly the same but now is:

$$\vec{f} = m \times \vec{a}$$

Everyone who has studied a bit of Physics recognizes in this equation a simplified way of Newton's dynamic fundamental law that tells us that, in an inertial referential, the force $\vec{f}$ exerted upon a constant *m*, body mass, causes an acceleration equal to $\vec{a}$. Notice we're replacing basic semantics, originated in mathematics, by a new semantics that's given through a translation of observed phenomena (the book that Nature is for Galileo) for a description in mathematical language. As one can see, we had to define certain basic concepts like mass, position (space/location), time, inertial referential, force and acceleration as a variation of speed in time. Now, the real number represented by *m* is limited to have values equal or superior to zero. The inertia referential concept is, as its name indicates, connected to the inertial movement concept. A concept that, since man started to try to describe movement in a mathematical way, and I recall that was started in Ancient Greece with the movement of the stars, only Galileo, whom around two thousand years later, managed to establish. We can conclude it wasn't easy to get there... The mass concept is another concept which is not totally evident. We can't confuse the mass concept with the weight concept. The weight concept would have to enter on the left hand side of the previous equation, since it's not more than one force, the force with which a body is attracted to the Earth. According to Newton, mass is nothing more than the quantity of matter and it represents, when integrated within the previous equation, the ability of a body to resist to a change of its state of movement when suffering the action of a force. The mass concept only acquires the meaning given by Newton when integrated within the previous equation. We call this mass, inertial mass in order to highlight the meaning I've just mentioned, since in the previous equation it represents the ability of a body to resist to a change of its speed, the inertia. This equation tells us that the bigger the mass, the smaller will be the speed suffered for the same exerted force.

- Hey, Argus, do you mean that a mathematical equation, in spite of being formally equivalent to an equation used by a physical theory, can never solely describe phenomena without implying a whole complex interpretation, establishing a complex web of matches with the observed phenomena? - asked Lucius, trying to sort out some doubts he still had.

- That's exactly what I've been saying - said Argus. - Otherwise there would be no need for the existence of physicists, because physical theories would be built by mathematicians thinking logically about beings, largely abstract, existing in spaces, also largely abstracts. In fact, mathematicians manage to build all that relations' web between existing abstract beings in abstract spaces and beings with those own spaces. The most amazing is that, sometimes, that becomes useful to describe a certain set of phenomena. That's where that "translation" is supposed to be made by physicists. The "translation" of the language in which the Nature book is written into another language, to the most precise language man has managed to build until today: mathematics.

However, it becomes necessary not to forget that mathematics is one thing and physics is another. Grammar and synthetic rules of a language are one thing and a poem is another. Equally, paints and brushes and the respective pictorial composition rules are one thing, and another totally different thing is Mona Lisa or the Virgin of the Rocks of Leonardo.

I would still like to add that sometimes physicists themselves develop that language. In those cases, physicists are the ones who develop mathematics and in practical terms become mathematicians. This way, mathematics becomes capable of describing phenomena in order for us to translate the book of Nature in a more accurate way. That's what happened with Newton when he needed to express a relation between force and variation of speed with time which is, as we know, acceleration. Newton was forced to develop the language for which he was making the respective "translation". Mathematics development state at the time wasn't capable of "translating" the relations he was now discovering in the "book of the Universe". For that he needed to use concepts inherited from others, such as Galileo's inertia concept, or introducing new concepts like the mass concept, for something that was already sketched by Huygens - proportionality between force and acceleration – could be now explicit by means of an equation previously written. But in order to write that same equation he saw the need to develop a whole mathematical technique that we presently call infinitesimal calculus. Newton's work was a hard one. He represented a kind of world reconstruction from a limited set of four postulates. It was a tremendous effort that took three years to accomplish, from 1684 to 1687, three years that Newton needed to write his most important masterpiece, actually one of the most important ones of the human cultural history, the *Mathematical Principles of Natural Philosophy.* After that gigantic effort, Newton's mental health deteriorated in a dangerous way. This only proves the dimension of intellectual effort that's behind the appearance of such a big work.

Argus stopped to think and Lucius took that opportunity to ask:

- Are you saying that Newton grabbed some concepts dispersed until then, introduced other ones from his own creation and managed to build a coherent basis to create his theory?

- Very well, Lucius – said Argus, adding: - That basis is always formed by non proven statements: the postulates. These are only accepted if they and the consequences deducted from them are, within certain proximity, in accordance with the phenomena they intend to describe.

Newton's mechanics postulates are three:

The first one is the inertia law that defines an inertial referential, meaning a referential in which a body not actuated by any force remains in the same movement state; that same movement state includes the rest state as a particular case. That principle is not demonstrated, nor experimented, since no one has ever observed a body where no force has acted upon. That would imply that body was totally isolated, which is a practical impossibility. We can show that while the forces that act upon a body are being diminished, its movement progressively approaches from an inertial movement, a straight and uniform movement without however hitting it.

The second postulate is the one that expresses through the equation I mentioned. An equation is only valid in inertial referentials, unless we introduce the so called inertial forces that appear only because we're not referring to the movement subject to the referential of inertia. It's what happens with the Earth's atmosphere. The big movements of the atmosphere suffer the so called Coriolis acceleration, which is a consequence of the Earth's rotational movement, and therefore our planet cannot be considered a referential of inertia for phenomena regarding atmosphere movements.

Finally, the third postulate is the one by which one states that a body upon which a force is exerted, exerts upon the body that acts upon it an equal force and in an opposite way.

These three postulates constitute the hard core of Newton's mechanics. From them, and from another postulate that quantifies the force exerted between two bodies at a certain distance from each other – the universal gravitational law – Newton's mechanics describes with a remarkable precision the local movement, it describes with great precision the macroscopic bodies position change within space when acted upon by forces. These bodies only meaningful characteristics are to possess mass.

- Was that what convinced the Newtonians of the 18th century that Newton had, as you said, created the big THEORY and not just a theory that, in spite of having enormous effectiveness, can be only applied to the scale in which we're observing phenomena? - asked Amadeus.

- That's exactly what happened – agreed Argus. – We can still admit to some extenuating circumstances in this case. Let's not forget that during two thousand years of Aristotelic physics not much was extracted and that now, in just some years, advancements were becoming evident. They were the extenuating circumstances. One perfectly understands those men might have been stunned with success. It's much less acceptable nowadays similar positions might be taken. Not regarding the Newtonian theory, of course, but regarding much more recent theories.

Physical theories are human constructions and, as such, can only describe phenomena at the scale we're observing them. We can never have the pretension that theories govern phenomena, which constitute reality. As I said, theories constitute a mere description of phenomena, the only manifestation we can apprehend of an underlying reality.

- What do you mean by that? – asked Lucius.

Argus explained:

- The Newtonian mechanics allows to determine, from the knowledge of position and speed within a material point, in a certain instant, and of the forces it's subject to, the positions it has been subject to before and the positions it will have later. In other words, by knowing the initial conditions we can know its positions in the past and also its positions in the future. This took some thinkers to say the world was deterministic. Everything would be previously determined and no freedom remained for bodies. It was precisely this reason that led Pierre-Simon Laplace to state if it was possible to know the positions and speeds of all bodies existing in the world; it would be possible to know all the past and predict the future. This is the position one names Laplacian determinism. A determinism from which all possibility's of free choice has been expelled. History showed us how naïve that position was. But it was an ingenuity we can understand these days. What we cannot accept is that nowadays one adopts similar positions regarding more recent theories. Nowadays, that cannot correspond to ingenuity. Nowadays, we're no longer authorized being naïve.

- And that happens presently? - asked Lucius.

- Yes – answered Argus. – When someone states that quantum mechanics “proves” the world is undetermined it falls into an identical mistake made by the Laplacian determinism. Such as the Newtonian theory, quantum mechanics is a theory that has overcome all scientific theory validation criteria. But we cannot fall into the same naïve mistake as the Newtonians did when thinking the world would obey in an absolute way to Newton's mechanics and gravitation. In the same way, the world doesn't obey in an absolute form to quantum mechanics. This theory only intends to constitute, at the scale we're describing phenomena, a good approximation to them. The problem with quantum mechanics is that the Bohr's interpretation of its formalism intends to reach an irreducible irrational residue. It states we can never reach a bigger intelligibility of the book of Nature. I would like to discuss this problem with you, but I'll have to leave it for later. I need to talk about a way of how we've come to this situation. This ingenuity I referred to is presently manifested by other means. Sometimes it even resembles the character of a grotesque caricature. An example of this is the case of certain “famous” physicists who stated that within few years they will know the origin of the Universe. But of course counting on that to become a reality they will need a huge amount of money. Without that, there is no deal. This is atrociously ridiculous. Since time passes by quite quickly, as an old teacher of mine used to say, these physicists must start getting up quite early in the morning to achieve that goal...

But seriously now, it’s necessary to state that a peremptory statement like the previous one proves, in the best of cases, an embarrassing lack of culture, even scientific, and worse than that it indicates a disgusting dishonesty. The lack of culture would lead us to tell them it would be better to start thinking about the foundations of what they’re doing not to make such a ridiculous statement. Dishonesty would force us to keep, like doctors say, a certain clinic distance in order to keep away from such unwanted company. It’s the same attitude that wise people take on regarding politicians that promise everything to win the elections… They are as dangerous as each other. These “politicians” twist and therefore discredit politics. These “scientists” twist and therefore discredit science. Science is something precious because its goal is to allow us to better understand the world that surrounds us. And that for our odds to survive as a species may increase. Therefore, science needs to be defended. But for that defence to become effective, we must say what it really is and not draw such grotesque caricatures. When one states that within a time period, whatever that one is, one will know the origin of the Universe, one must state which the postulates to base on that statement are. When making such a statement, we must mention all non provable statements that support it. This statement is integrated in a theory project and, as I never get tired to refer: no theory is THE THEORY in capital letters; if no theory project can ensure by itself the theory statute, by a majority of reason, it cannot present itself as THE THEORY. When a physicist makes a statement like that one I've been criticising, he presumes the theory projects in which he based himself upon are correct. He believes the Big-Bang happened when, and this is necessary to underline, there is no irrefutable evidence of that. The Big-Bang is no more than a mere possibility. But this is put aside on purpose to guarantee obtaining such substantial financing.

- Are you saying that the Big-Bang never existed? – questioned Amadeus, astonished.

- No, I'm not saying that. I'm just saying there is no irrefutable evidence of such an existence – replied Argus. – I even think it didn't exist. The observations told to "prove" the Big-Bang existed can be explained in another way.

- How? – asked Lucius.

- I'll explain that later – said Argus. – But before I must prepare the way to get there. Now, I call once again your attention for the fact it's not lawful to admit there is an identity relation between a theory, whatever it is, and reality. This relation can only be an analogy relation.

Physicists are "translators" of the "book of Nature" for a language that is under permanent evolution: mathematics. Why is it that 2,500 years after the so called science emergency (and we mention emergency only because we can relate it easier to what we today call science), we would have reached a development of that language in such an elaborate way that it would be capable to relate the original "text" with the maximum details? Speaking of 2,500 years is to talk about a very short time period. Short if compared to the age of the Earth or to mankind's age. History is far from reaching its end. Mathematics will continue to evolve and the original "text", that "book of Nature" didn't allow us to read all its pages yet.

Continuing with this analogy, we can say that there are sentences written with such lower case "letters" that, with the present methods, we still can't read them, or with such "remote" letters we still don't know they exist. This is the book we're translating with the risk of not having a global vision of the original masterpiece. The physicist that made the previous statement I criticize so much could naively believe that the gross financing he intended to obtain would allow him to access all lower case "letters" that compose the text he intends to translate. However, it would be useful to inform him that when we say there are still no methods necessary to read such lower case "letters", we're not referring ourselves to mere experimental techniques that are more elaborated, we're also referring to the need of always reporting ourselves to the vision of the world associated with a determined theory, the conceptual basis by which that experience makes sense. As I mentioned before, an experience is not more than a question we make to Nature. Therefore, for an experience to make sense it's crucial for it to belong to a conceptual basis. We can as well, in certain cases, be looking to lower case "letters" of the "book of the Universe", but without understanding them because the conceptual basis we support on doesn't allow it. The "syntax" and "semantic" of the original "text", the deepest meanings associated to phenomena chain, are not yet accessible to us. Sometimes it's necessary to change the point of view, the conceptual basis, so we can see some coherence in that "text".

For all of this, making such peremptory statements like the one we've been talking about is to take for granted the assumption of believing that the vision of the world behind that statement, or the conceptual basis that supports it, corresponds exactly to the profound meaning of such original "text" - the thing itself – to the noumenon of Kant's words. But Kant's thing, such as he described it, is not entirely accessible to us. We only contact with phenomena that aren't more than the result of a complex interaction between the experimental subject and the experimented object(s). It's through the phenomenon that knowledge becomes objective. In a certain way, the phenomenon creates its own object of knowledge. There are no pure facts. Sensitive experience data is created by us from the existence in ourselves of time and space concepts, the sensitive forms according to Kant. That may happen in a newborn because he can't relate them with the records of a memory still inexistent, or with the categories only the prolonging of existence may develop. A pure fact, in case of existence, could only exist isolated. Not a phenomenon. A phenomenon will always be a part of a whole.

A pure fact transforms itself into a phenomenon when integrated in a pre-existing conceptual frame. And that integration demands the subject's action by using understanding ways, categories according to Kant. When we use the relation categories, similarity, non-similarity, whole or chance, we're inevitably integrating that phenomenon into a determined set of phenomena that are as such because they can't exist in an isolated form.

- What do you mean by that? – intervened Lucius, intrigued.

- I can offer you an example taken from the history of physics. The Aristotelians, who defended Earth's immobility at the centre of the Cosmos, used as "evidence" to that immobility the fact that by throwing a rock in a vertical direction it would fall in the same place from where it was thrown from. If the Earth was moving, they said, the rock would always fall in an opposite direction to the Earth's movement. Such as if one intends to recover an object that inadvertently has fallen out of the window of our car while it is moving, we must stop and reverse a certain distance, because the object will remain behind. By trying to explain this fact, integrating it in a certain conception of the world in which the Earth was still and where all stars circulate around it, they had transformed it into a phenomenon, in the same sense as Kant did. This argument was interpreted by Galileo in a totally different way. For this physicist, that phenomenon was totally irrelevant because if the Earth was either stopped or moving, the same thing would happen.

It is the famous example Giordano Bruno invoked in his work *Cena delle Ceneri* (The Ash Wednesday Supper), written when he travelled to London and Galileo used later, the boat sailing in calm waters. A rock dropped from the top of the mast falls, for the man who dropped it, parallel to the mast regardless of whether the boat is moving. The same would happen if the boat was motionless.

For Galileo, the Earth would be our "boat" and the rock dropped in the vertical direction would fall on the same place from where it had been dropped whether the Earth was standing still or moving. The same phenomenon, invoked by Aristotle to prove the Earth's immobility, because it belonged to a certain vision of the world, was considered by new Physics as irrelevant. It would, therefore, transform itself into another phenomenon because it belonged to another conception of the world.

In these cases, the totality category is being used. In fact, in this entire discussion one is using categories considered by Kant.

The relation and analogy categories – for Galileo's disciples the rock movement on the boat is related to the rock movement on the Earth establishing, this way, an analogy relation between the Earth and the boat. And by establishing this analogy relation between the Earth and the boat, Galileo's followers are also integrating the phenomenon observed in another Physics that was then starting to outline in which the Earth no longer was motionless at the centre of the Cosmos but moving.

Causality category was also used, because Aristotelians defended that the cause for the rock to fall at the same place from where it was dropped was the Earth's immobility. And by denying that relation of causality Galileo's supporters were really using the causality category, denying its application to this case.

For Kant, it's the phenomenon that makes knowledge objective. As we've just seen, we are the ones who largely create the object of our study. The scientific revolution initiated by Galileo is a clear example of that. The Platonic answer that started the first scientific research program where man played a role within the astronomy domain is another example of that. This is what Popper meant when stating that all observation is "theory-laden".

- You're saying that the object of study is largely created by us. There is no danger if, by saying those words, we lead some spirits to see a solipsist position? I don't think that's what you've been defending - intervened Lucius.

- Of course not - said Argus. – I take a realistic philosophical position, meaning I defend the existence of the so-called reality which largely is independent from us. It's our apprehension of that reality that depends almost entirely on us. Kant's position does not lead to solipsism. I think that science has demonstrated, throughout history, that it is reasonable to believe there is something beyond the subject. To believe in a world as a pure creation of my spirit is to me something I cannot believe in. When I state, following Kant, that the study goal is largely created by us, I only mean that science creates its study objective, because it inevitably depends on human capacities. Human capacities that are related to the existence and effectiveness of practical and theoretical tools available at that time. And the creation of that ontology depends, of course, on the subject itself.

When Plato introduced in the history of human culture the ontological division of the world in two parts - the intelligible world and the sensitive world - he inevitably used categories such as similarity, non-similarity, causality and accident, amongst others. That way, when the Ancients looked into the skies they saw them, creating its object of study, in a completely different way from the one we do now. By adopting the platonic-aristotelic ontology we were largely creating its own object of study.

When Copernicus advanced with the heliocentric model, he created a new object of study. When during the 30's and the 40's of the 19th century, astronomers started to understand the existence of galaxies with several forms, understanding there is a Universe beyond our galaxy, the object of study has significantly changed. When the abbot Lemaître proposed the Big-Bang theory, he wanted to force us to look at the Universe in a determined way. When Hoyle proposed its stationary Universe model, he wanted to lead us to look at it in a completely different way from the one with which most physicists look at it presently while adopting the Big-Bang model.

- So, you're saying that a model has a certain metaphysic associated to it? – asked Lucius.

- Of course – answered Argus. – I say even more. It is impossible to build a physical theory, something far more complex than a simple model or system, without using a certain metaphysic. To exemplify the difference between model or system, on one hand, and theory, on the other, one must think about the difference between Copernicus heliocentric model or system and Newton's mechanics and gravitation. In spite that in a certain way these are consequences of it, they end up integrating the model within a far more general and fertile frame.

A physical theory (and when I talk about physical theories I'm talking about the great physical theories such as Newton's mechanics and gravitation, the electromagnetism and the last big theory we managed to create, quantum mechanics) can only be built from a world's point of view that intends to be minimally coherent, at the scale of what we are trying to describe. That is the vision of the world that constitutes a metaphysic as a last resort. Models or systems themselves support each other in a determined metaphysic or ontology. The Copernican model or system is based upon a certain metaphysic of a Platonic basis. But that model would drag, not explicitly but implicitly, the destruction of the Platonic division of the cosmos into two sub-cosmos ontologically different. Galileo made it explicit. Newton, regardless of the statement "I do not create hypothesis", during the controversy with Leibniz, by a third person, regarding gravitation, was compelled to introduce many "hypothesis" along his activity as a science man, by resorting to clearly metaphysic concepts. Within the optics domain he admitted the existence of ether that would fill the whole space. In the neighbourhood of the separation of two optical mediums, such as air and glass, the density variation of that ether would be the cause of the refraction phenomenon. Also within the optics domain, he admitted, as I've said before, that the luminous corpuscles would have "accesses" of easy reflection or of easy refraction, in order to explain the decomposition phenomenon of the colours of the rainbow in thin strips. However, the bigger of those "hypothesis" was the one admitting the existence of an absolute space and time as sensors of God, as organs of God's senses, through which He would apprehend the world and could act upon it. Gravitation was for Newton a clear manifestation of God's action in this world. If Newton could have kept faithful to a unique metaphysic vision of the world, it would be a metaphysic associated to a world made of corpuscles moving in a straight line when not acted by any force, that could either be a "lay" force, such as the ones we can exert upon the bodies, or a "divine" force from which gravitation would be a manifestation of.

This was a metaphysic that Newton used as the support for its physics. Newton, such as all men of science of his time, was a convinced Christian and his physics would serve to prove God's own action in the world. As you can see, we can state there was no confrontation between the Christian faith and the new ideas. Many of those related with the defence of the new science were men who believed in the message of Christ, but did not hold on to a textual interpretation of the Bible. Galileo said it explicitly. The God he believed in manifested Himself in all that exists and not in any book written by men. They intended to expurgate the Bible of the superfluous and only recover its essence, its message. What happened was a confrontation with Christian religions or churches - institutions that intend to normalize individual religiousness with the goal to conquer and maintain power.

- The spiritual power – Amadeus tried to enlighten.

- The power! The power without adjectives – said Argus. – The power to impose a vision of things, which states to be expressed in books seen as being the word of God. Books in which the whole Truth would be exposed. Therefore the latent conflict with all scientific activity. This one, in order to progress, couldn't be tied to dogmas, to myths. Science, although looking for the most profound meaning behind the phenomena we observe, admits the meaning he conquered in the meantime is always provisional, since the translation is never identical to the original "text". It is important to point out that the existence of those myths are part of a clear anti-democratic position. They maintain that these dogmas only regard those who believe in the myth. But if they maintain that today, it is because a long resistance reduced the power of those who lead those believers. Galileo was condemned because in the Bible it was said that God had stopped the Sun. If God had stopped the Sun that meant the Sun was moving. If Galileo and before him Copernicus argued that the Sun was still, they were contradicting what the Holy Scriptures stated. That was one of the accusations that condemned Giordano Bruno to the fire on 17th February 1600. Copernicus's book was placed in the Index in 1615. Galileo was condemned to a life home arrest in 1633.

Galileo argued that we should not hold on to a literal reading of the Bible. Before him, the Italian humanists defended the "doppia verita" (double truth) doctrine that affirm the existence of two truths, the truth of faith and the truth of reason. This was a doctrine that was born a few centuries before in the Arab Iberian Peninsula when Averroes introduced it into the Islamic myth to defend science and the creation of a more free society.

In science there are no dogmas, only principles, postulates, that are non-demonstrated affirmations, only accepted if they and the consequences that we deduce logically from them are in approximate accordance with the experimental data and the phenomena. It is a much more democratic position. Maybe the best name we could give those postulates is the name that one of the greatest men of Hellenistic science, Archimedes, gave them: requests. This name would remove all the arrogance that some (bad) scientists wrongly give to those postulates. Science cannot be arrogant because arrogance is profoundly incompatible with its true reason of being. Arrogance is only characteristic of those who think they are owners of the Truth. The defenders of the myths can be so. A man of science is not authorized to be so. A man of science does not own the Truth. He can only say with recourse to physics that to the scale in which they try to describe phenomena, physics theories increased our capacity of action in the world. To a more profound scale it may be that the laws, the rules, that we have managed to establish up until now ought to be re-interpreted by another theory that may transform the postulates, that is, the non demonstrable affirmations that are the base of the actual theories into mere corollaries, i.e. demonstrable affirmations – stated Argus.

- Science was born from a fight against dogmas and you are now saying that nowadays there are dogmatic scientists? – asked interested Amadeus.

Argus answered:

- Only those who do not understand what science really is. Understanding science as it should be understood makes this position inadmissible. I repeat that men of science who are protagonists of the science revolution of the 17th century were all Christians. We can mention Copernicus who was a clergyman and Galileo, Kepler, Descartes, Huygens, Newton and Leibniz, and others. It was inevitable that they were. This is because only a religious monotheistic concept allowed these men to believe that the world was a work of a God and that as wizard apprentices that world would be intelligible. This means taking to the extreme the original sin that as we all know consists of the usurping of the knowledge of the gods by men. The myth of Adam and Eve in paradise or the myth of fallen angels in the book of the patriarch Enoch, presently no longer linked to catholic belief, represents this. Without becoming fully aware of it, by believing that the world was comprehensible these men re-crossed the border that myths wanted to remain closed off. This time, with obstinate determination. They were entering again into the territory of science now with a new vigour. This territory that is essentially incompatible with the acceptance of any myth. Their God will stop being the God of myth. He will now become the God of reason. This is how the doctrine of "doppia verita" would end up dying at the hands of those who initially would have defended it.

- Why do you emphasise that it was the believers of monotheistic religions that were the heralds of the scientific revolution? – asked Amadeus.

Argus continued:

- The new science was born on the shores of the Mediterranean mainly because two things happened there that did not happen in any other region of the Earth. On one hand I am referring to the birth of Greek naturalist rationalism, something very singular in which natural causes for natural phenomena are searched for and on the other hand I am referring to the existence of monotheistic religions, namely the Jewish and the Christian. The first created the belief in the existence of a superior intelligence that created that cosmos.

- But that was not something that appeared in a clear way – answered Amadeus. – We know that in the Renaissance the Jewish kabala, hermetism and astrology and others invaded the more cultured minds. Many humanists are a clear example of that. In Florence, Picco della Mirandola who knew several languages became interested in the kabala. The Médicis and the main mentor of the Platonic Academy of Florence, Marsílio Ficcino, promoted the translation of the books attributed to Hermes Trimegisto because it was thought that they were linked to a knowledge even older than Greek knowledge. It was believed that they were written in the time of the exodus of the Jews from Egypt and for that reason they were linked to the origins of the Jewish/Christian faith. They would contain a more powerful truth than the one inherited by the Greeks. We now know this to be false because they were written in the Hellenistic period when Greek rationalism started to become decadent.

- I agree – answered Argus – But it is necessary to emphasise that although there was this undeniable decadence it was in the Hellenistic period that scientific books crowned all the Greek-Hellenistic period. Let us not forget Euclid with his *Elements*, Archimedes with the first mathematical laws of physics, Apollonios with his book *The conics*, of Aristarchus with the first proposal of a heliocentric Cosmos and with the first measurements of astronomic distances, Eratosthenes with the first attempt at measuring the Earth’s dimensions and Hipparchus, the great astronomer of this period, who successfully continued the research program in astronomy proposed by Plato, preparing the way so that three centuries after, right in the middle of the Roman Empire, Ptolemy crowned this program with the book *Mathematical Syntax* that the Arabs named *Almagest*. By the way, we should not forget that Ptolemy also wrote *Tetra-biblical Syntax* which was a far less rationalistic manifestation. I agree with you because astrology and astronomy had a promiscuous relationship until the 17th century. As a matter of fact, the motive for the beginning of the astronomic observations was related to the attempt to predict the future, of making astrology, but even that prediction was integrated in an ordinary attempt at finding non theological causes for different things.

- Are you saying that astrology, Kabala and Hermetism and alchemy were also manifestations of a search for a hidden knowledge and in that sense could be understood as a consequence of this complicated mixture between a theological, monotheistic concept and naturalist rationalism that, as you well said, only appeared on the seafront of the Mediterranean? - intervened Amadeus.

- It is true – answered Argus – Also in the 16th century humanists embraced all these paths, but it was from that big confusion that the new method emerged, the new science. It was from that big confusion that men appeared like Copernicus who, without a plausible reason, placed the Sun in the centre of the Cosmos; like Tycho Brahe, who started the meticulous task of observing the sky, the purpose of this task was to find out the position of the stars in the most accurate way possible so that better astrological previsions could be made; like Kepler, who in his *Misteryum Cosmographycum* thought that there were only 5 planets because there were only 5 regular solids. This would have been, according to Kepler, the secret that presided over the construction of the Cosmos by God. Of course there are not only 5 planets and for that reason this idea of Kepler’s does not make any sense nowadays. But Kepler did a lot more than that. He arrived at his two first laws in the book he wrote in 1609, the *New Astronomy* and his third law because he looked for the music made from the movement of the celestial spheres and that our ears could no longer hear because they were too used to it. As we well know, this third law appeared in the book *Harmonices mundi* of 1619. But this third law had more to do with a harmony for our reason rather than for our senses. As you can see, we can consider that all this is a consequence of the double belief that this world was created by an omniscient Being on one hand and a belief in our capacity of understanding that work on the other hand.

- But did not the Catholic Church immediately understand that route was dangerous? – asked Amadeus.

- Only when Galileo started his propaganda campaign of Heliocentrism – answered Argus – But the success of this new methodology and the new science was such that the Catholic Church soon lost its ability to oppose it. Naively, Galileo wanted to convince the roman curia that Heliocentrism would be the most worthy system of divine omniscience and omnipotence. The roman curia that was attached to a literal reading of the scriptures did not accept it. Galileo claimed that those scriptures should not be interpreted literally. The Catholic Church did not accept the argument and condemned it. As we know, it was only at the end of the 20th century that the Catholic Church apologised for the mistakes that were made and reinstated Galileo. About 350 years later! Galileo did not need that anymore…

- Does this mean that between the Catholic Church and science the friction was over? – asked Amadeus.

- No way – answered Argus – We must not forget the resistance towards Darwin's evolutionist concept. Once more, a literal reading of the scriptures opposed this. Even today the position of the Catholic Church towards the evolution theory is not pacific as the theory comes into clear confrontation with the doctrine. Teillard de Chardin tried to reconcile both, transferring the divine touch to a previous stage, to a primordial Cosmogenesis. Today people are trying to restore unsteady creationism by talking about "intelligent purpose", that is, a divine premeditation in creation which led to the appearance of life. Genetics continues to indicate that there is no divine touch in the origin of life, but myths continue to resist a total vision of things. "Intelligent design" has nothing to do with the pre-established harmony of Leibniz. The pre-established harmony of Leibniz had a lot more to do with the possibility of the world being understandable than the pretension that at any point in time a divine touch went against the laws of this world imposing something strange to it. In a certain way it violated it and so denied us the possibility of one day understanding it.

The essential cleavage between science and myths resides here exactly.

The myths need to be pessimistic; they defend pessimism in relation to human capacity to understand the "book of Nature". Science is optimistic. Science believes that we can go on understanding Galileo's book of the Universe so that we do not continue to "wander in a dark labyrinth". Science has as its only objective, like utopia, to disclose those secrets. But Science knows that the knowledge it produces is temporary. However, it believes that it can always develop it. The myth goes on exploring the path that still needs to be travelled so that it can continue to "breathe". It continues to use the unknown in the search for a barrier to that rationality, a barrier that can never be overcome. That is its ultimate trench.

It became content when it found a strong argument in orthodox quantum physics. In this physics there is Bohr's principle of the complementarity that is the basis of the Bohrean way of interpreting quantum formalism. In its essence this principle translates a profound conviction of Bohr's that "there is an irrational, irreducible residue" and that this irrational, irreducible residue "was now expressed in a mathematically lucid way". The second sentence that is in inverted commas is from Bohr and it refers to the difficulties found until then by the human race to describe phenomena. The first sentence in inverted commas is an affirmation of Niels Bohr's philosophy teacher, Harald Høffding. The latter had defended the existence of that irrational, irreducible residue in psychology, that is, in the study of the spontaneous functioning of the human spirit. He thus defended the existence of a complementarity principle in psychology. The whole functioning of the human mind, even in its most elaborate forms should be "psychologically possible". That is why this principle was propagated inexorably to all those manifestation forms of the human mind. He himself had undertaken to transpose it to philosophy. He was not a man of science but he defended the inevitability of its extension to science. It was Bohr who undertook to do this.

This is one of the last trenches in which myth finds shelter in the field of physics. In biology, that trench resides in the argument that life appeared in a sort of touch of magic that we will never understand.

- In any case that position is different from the one the Church took on when modern science was born or when the theory of evolution appeared – Amadeus pointed out.

- That is so – answered Argus. – The Catholic Church no longer holds on to a literal interpretation of the Scriptures. It has already abandoned that trench. Not because it did not want to but because it cannot. History taught it that the use of that type of argument does nothing more than make it ask for forgiveness for the mistakes made sooner or later. Its methods are more subtle nowadays. They went on to the trenches that I mentioned a minute ago. Other Christian confessions do not adopt the same attitude. We know that in certain states of the USA teaching the theory of evolution is not allowed. In other states it is allowed as long as both the evolution theory and creationism are taught in confrontation. Some radical Christian sects impose it. Nowadays this is only a manifestation of mediocrity. In defending creationism against the project of the theory of evolution they adopt an attitude that surpasses the mere fight between scientific paradigms, in which rationality and empirical evidence represent an exclusive role. Against all the empirical evidence they impose a dogmatic vision that radically moves away from the normal confrontation between competing programs of scientific research. They become ridiculous.

- Do you mean to say that there is a deep cleavage between Christian doctrine or any other religious doctrine and modern science? – asked Amadeus.

Argus answered:

- If we take texts written about 2,000 years ago as doctrine even only those that the Catholic Church considers part of the canonical Bible, the Koran of the Muslims, or the Torah of the Jews, then there is a clear antagonism between science and the faiths. Only believers can consider that in those texts there is the Truth, transforming them into dogmas. We cannot achieve that “Truth” rationally. It is a mere act of faith that leads believers to accept it. It is the acceptance that those writings are emanated from God.

In the creation of a scientific theory we introduce postulates, that is, affirmations that are not demonstrable. However, we only accept them because they and the consequences that we take from them logically are in accordance, within certain approximation with the experimental results. Well, in religion this does not happen.

In religion, believers accept that the Divine character of those texts is unarguable and as such transform them into dogma, into indisputable truth. I even dare to say that it is a non democratic position. Whoever adopts it shows that he is convinced of owning the Truth. It is a dangerous position because it can lead to and has led to acts of disrespect for the freedom of those who do not accept those dogmas, or because they believe in others, or simply because they do not believe in dogmas. Let us not forget the many people who were burnt alive in the time of Galileo for questioning the dogmas of the catholic doctrine. Let us think of Giordano Bruno, who was burnt alive, as we made reference to, on 17th February 1600 in Rome. A little more than four hundred years passed and Giordano Bruno was not the last person to suffer this horror. In science and particularly in physics there are no dogmas, only postulates or as Archimedes called them more appropriately: requests. Referring to physics we asked people to accept them because from them we can build theories that prove some usefulness in the understanding of the world around us. These postulates allow us to build instruments unconceivable until that moment as a last resort.

But I emphasise again that we should not have any illusions.

Those theories do not constitute any Truth in the sense that beliefs attribute to Truth. They only constitute useful but incomplete approximations to reality but even though they are incomplete they managed to radically change our relationship with the world in a little less than three hundred and fifty years.

Popper made a point of marking out the border between what science is and what it is not. The popperian demarcation can be interesting to try to establish the borders between science and myth. But the previous observation is more significant. The possibility of an affirmation being refuted for it to be considered scientific, according to Popper, can be interesting to start a debate about the problem of demarcation between what is scientific and what is not. But even Popper found himself obliged to add that a theory, or I would even say a project of a theory, could survive one or more refutations. To say what science is, what a theory is, it is necessary to confirm if the three criteria that I referred to before are verified, namely the one theory allowing the construction of new instruments that increase our capacity of action in the world. It is not accurate to speak about falsification of a theory. Instead we should speak about the establishment of limits of their applicability. But that only happens when a new theory emerges that describes more phenomena than the first one described. In any case, this new theory has evidently to verify all the criteria that I mentioned.

- We have been defending the usefulness of science. Even if it is to practice something that is commonly regarded as harmful? – interrupted Amadeus, continuing:

- The so-called progress has not managed to make people happier, making their relationship with the world more harmonious. We pollute the world, there is now a quotidian life that for many people is a lot more distressing, with long journeys to work, there are weapons that can even destroy the human race, etc, etc, etc…

- You cannot attribute to science and knowledge the responsibility of those difficulties. The attempt to better understand reality is not responsible for the bad use of that better understanding – answered Argus. – If that were so we would have to ask: when should it have stopped? When we started using the first rudimentary tools, tools that appeared before any scientific theory? When we learnt to control fire? When we invented the wheel? It is a senseless question. Knowledge is not responsible for the bad use of instruments that allow us to build. Knowledge is something fundamental so that we can perpetuate as a species. A simple tool like a hammer can be used to nail something or it can be used to kill another human being, by crushing his head. Well, we all know that a judge would not accept that the responsibility was of the hammer, or of who made it, or even of the first hominoid who idealized and built the first instrument similar to a hammer…The responsibility is always of the person who uses that instrument, be it a human being, a nation or those who defend a certain ideology. The responsibility is always of a human being or group of human beings as citizens, as political beings. Not science. It was not nuclear physics that was responsible for the bombing of Hiroshima and Nagasaki. Nuclear energy can be used for pacific means or not. The choice and responsibility are exclusively ours.

- I agree – intervened Lucius, adding:

- But what you said about Truth revealed of the different religions cannot apply to different ideologies for similar reasons?

Argus answered:

- I totally agree. The process is similar. There are people that after a faith crisis adopt a certain ideology in a similar manner to the one that was the basis of their initial belief. Other people, even without going through a faith crisis adopt the same position. The problem is essentially the same. It is in the belief that the Truth can be found in a book, or group of books in which a certain ideology is founded. A Truth that also cannot be argued. This applies to all and not just a few.

- In science is there not the same situation? – asked Amadeus.

- There should not be – answered Argus. – In science there should be no place for myth but only a place for constant curiosity in the search for an ever deeper approximation of the meaning of the "book of the Universe". Sometimes, this spirit is cheated by people to whom this objective is not a constant priority and who transfer the problems detected in the function of society in general into the scientific communities. The fights for power, the fight for careers are things that happen in the quotidian and are almost inevitable in a scientific institution. They are harmful to the primordial objective of scientific activity: the incessant search for the profound meaning of "text" that we want to translate.

- You said a little while ago that Newtonian physics aimed at proving the existence of God? – asked interested Amadeus.

- Yes – answered Argus. – It was natural for Newton to want that. But History showed the ingenuousness of this position. This naive pretension did not manage to survive. As we know, the world is more complex than Newtonian physics and metaphysics wanted to be.

Science does not aim to prove or not the existence of God. The most sensible position that we can take regarding any theory is to consider that it is only an attempt at describing the phenomena to the scale in which we are learning. No theory can be considered THE THEORY that is, as an accurate description of all known and still to be discovered phenomena. When I refer to a great physical theory, I do not talk in any way about the THEORY, that is, a theory that aims to be definitive and to which all phenomena apprehended in the past or to be apprehended in the future "obey". You only have to talk about great physical theories, that is, use the plural for this naïve vision not to be assumed. Even if it were possible to create in the future a theory that unifies all the great theories known today, even then we would not be able to consider it THE THEORY. There will always be phenomena to which we will not have had access that will prove once more the ingenuousness of such a vision. The translation is never identical to the original text.

- I agree with nearly everything you said – intervened Fabrus – As you can imagine I just do not subscribe totally to the affirmation that science demonstrated, throughout its history that it is reasonable to believe there is something besides the subject. As you know, Niels Bohr would not subscribe totally to that affirmation. He would say that it would be taking it too far, because science or quantum physics showed that the subject had a more important role in the building of knowledge than even Kant would admit to. As you know, according to Bohr, we can only speak about what we measure, not because before the measurement we do not know the value of the measured size but because before the measure we are not allowed to know if what we measure exists or not. The only thing that we can speak about is a group of potentialities with a determined probability that in a future measurement will be observed.

Let us imagine that we want to determine the position of a certain quantum particle. As you know, it is necessary to know the wave function that is the solution of a certain equation like, for example, the equation of Schrödinger. According to the Bohrean quantum mechanics that wave function allows the calculation of the distribution of probabilities associated to possible locations in which the particle can eventually be detected. Before we detect it, before we check in which position it will be detected, the only subject we can talk about is that same distribution of probabilities. Before the measurement, we cannot speak about the position the particle is in but only of the potential positions in which we can detect it through a later measurement.

Before the measurement we do not know the location of the particle. The most that we can say is that there may potentially be in all regions of space in which the wave function is different from zero. When we measure its position it is when it "materializes" in the position it is detected in. This is when the potency becomes an action.

If we state that the quantum particle was in the location we detected it in before the measurement operation, we would be saying that quantum mechanics is an incomplete theory. This position is an inevitable consequence of the principle of complementarity introduced by Bohr in 1927. This principle constitutes the touchstone of all quantum mechanics. What this principle does is to relate the indeterminism that we spoke about in the position measurement of a quantum particle with the indeterminism in the speed measurement of that same quantum particle. But what we said for the position is still valid. That is why I do not agree with you when you state that science would have demonstrated throughout its history that it is reasonable to believe that there is something else besides the subject.

- You are right in pointing out that question, which is unarguably the crucial theme of all physics of the 20th century – agreed Argus – Although we have different views about this you are someone with whom one can discuss things. It would be good if all physicists when they start learning quantum mechanics were obliged to read the two first works presented by Bohr. The first was done in the Conference at Lake Como and the second in the 5th Solvay Conference, held in Brussels in the autumn of 1927. Maybe then they would understand the deep meaning of Bohrean quantum mechanics and not only learn to apply quantum formalism to the solving of certain problems, which is also important.

- What are you two on about? – interrupted Amadeus curiously.

- The fundamental problem of physics of the 20th century that overflowed into physics of the 21st century – answered Argus, adding:

- But today it is a bit late. The theme is complex and we should talk about it more carefully. Let us leave it for a next meeting.

We said goodbye and I was interested in continuing the discussion as soon as possible.

THIRD JOURNEY

It was Lucius, once again, who promoted a new meeting. He intended to clarify something that had been hovering above the previous dialogues. For that reason, he invited us into his home.

Upon our arrival, our host sat us around a small table filled with drinks fit to please everyone, tea, cakes, and other appetizers. After the usual chat and after everyone had been served, Lucius opened the dialogue.

- I would like to clarify an issue recurrently referred to in our previous dialogues. Nevertheless, Argus and Fabrus' diverging positions were not deeply explored. I mean the divergences outlined on the fundaments of quantum physics. A theory which, according to Fabrus, would be the best and most precise theory that mankind could ever conceive.

- I can understand your interest – Argus began. – If presently there is any scientific controversy with profound epistemological implications, it began in 1927, on the fundaments of the quantum theory. The quantum theory rose, and still rises, such deep issues, issues that question deeply such rooted convictions of our relation with the world, that, inevitably, such controversy lingered on until the end of the 20th century, and extended to the 21st century. The Bohrean interpretation of quantum mechanics questions the possibility to proceed within the path created by Galileo's physics up to 1927. It may sound weird, putting it this way, but when we come to understand the quantum theory, and to do so we need to understand the consequences of Bohr's principle of complementarity, we realise how deep we have plunged ourselves in more profound gnoseologic problems.

In fact, what the principle of complementarity means, what it stands up to the most, is the existence of an irrational and irreducible residue, which, no matter how hard we try, we will never be able to go beyond. I usually employ a sentence composed of two sentences from two different characters, but which are deeply related. I am referring to Herald Høffding, Niels Bohr's philosophy teacher, a friend of his father, and later on also his friend. This author claims that *there is an irrational and irreducible residue* which, no matter how hard we try, we will never be able to go beyond. Bohr adds that *it (the residue) is now expressed in a mathematically lucid way*.

If we join both sentences together we obtain the following: *there is an irrational and irreducible residue, which is now expressed in a mathematically lucid way*. This sentence holds the fundamental problem raised by the orthodox interpretation of quantum mechanics or the Bohrean interpretation or, still, the interpretation of Copenhagen.

- You mean, ho Argus, that science itself, in this particular case, physics, would have substantiated a limit to our capacity of rationally understanding the world? – Amadeus asked, intrigued.

- Bohr most certainly defended that – Argus confirmed. – And more, all those who coherently defend the orthodox interpretation of quantum mechanics have to be fully aware of that fact. To accept this interpretation is to resign from understanding, using the rationality we began to build in Ancient Greece, regarding certain observable phenomena.

To better understand the origins of this great controversy it is useful to analyse an interesting and significant example taken from the history of science. The phenomenon of interference, for example.

This phenomenon is observed when we make light from a source go through two holes placed at a certain distance. We may illustrate this situation through the same sketch we have already used in the Second Journey and which I will again draw here:

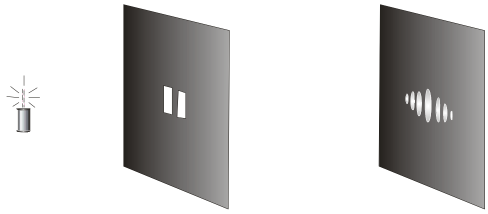


Fig. J 3.1 Young's experiment.

As we have seen before, this experiment was made for the first time in the 1800s by an English doctor called Thomas Young. That is the reason it has been named Young's experiment.

We also know that Augustin Fresnel, between 1815 and 1821, managed to explain this phenomenon from a wave conception of light. According to this theory, the light emitted by the source is composed of a wave, which upon arriving at the surface with the slits, originates two waves. These two waves propagate and overlap themselves. On the target, which is placed relatively apart from the holes, we will observe the result of this overlapping. This result is precisely an interferential pattern. Fresnel managed to explain this phenomenon resorting to the wave conception of light.

What matters here is that this phenomenon seems to makes evident that light is no more than the disturbance of a subtle medium, a medium which the 19^{th} century physicists baptized with the Aristotelic designation of *ether*. This light wave theory came to be accepted by the scientific community. After 1873, when Maxwell published his *Treatise on Electricity and Magnetism*, this theory was integrated into a more general frame of Maxwell's electromagnetic theory.

From then on, light would be no more than a simple particular case of electromagnetic waves. It would be distinguishable from others only because our eyes can perceive it. We can therefore say that light is formed by electromagnetic waves of the visible bandwidth.

- I do not see a controversy so far - Lucius interrupted, intrigued.

- Of course not. - Argus replied, smiling - If there was a problem at the time, the Newtonians had it, since they, rather reluctantly, abandoned their corpuscular conception of light. They offered some resistance, as I have told you before when we discussed Poisson's luminous point, but they ended up recognizing the superiority of the wave conception of light to explain optical phenomena.

There has been a change in paradigm here, in the particular case of optics, later integrated into a more general framework of electromagnetic phenomena. This change was based upon the superiority of the mathematical description of these phenomena from a wave conception. However, even after they compromised and admitted the superiority of the wave theory, during the remainder of the 19^{th} century they tried to uncover the mechanical properties of the medium which supported electromagnetic waves. If they were to admit the existence of such waves, they would have to integrate them inside the Newtonian paradigm, assuming the subject of the verb to undulate, the medium which supported those waves, would be kept within the borders of the Newtonian physics.

Lucius tried to clarify his ideas.

- But such a change in paradigm did not create a boundary to our capacity of gradually understanding the phenomena we observe, in a sense of making them intelligible. To go from a corpuscular description to an undulating description of light may have been hard for those who invested their whole lives in trying to develop the first one, but I do not think this would distress our trust in the path which Galileo has drawn for us. Like it has been said, this path intends to mathematically describe the observed phenomena, even if Galileo restricted it to the mathematical description of the mere change in position.

- So far - Argus continued – there is no epistemological problem that leads us to mistrust our capacity to rationally understand the world. Nothing that can make us hesitant upon our ability to build an increasingly better mathematical description of physical phenomena.

Surely a wave is not a change in position like the ones Galileo was trying to describe. But it can be interpreted as a result of changes in the position of the particles that form the medium which supports those waves.

The problem has emerged already in the 20th century, when Einstein and his explanation of the photoelectric effect introduced the concept of the light-quantum in physics, which we now refer to as photon.

The reasons which led him to introduce such a concept were mainly derived from a set of experiments performed by Hertz, a German physicist. This physicist made luminous radiation fall upon a metal plate, such as zinc, and verified that electrical current was produced. This phenomenon was called photoelectric effect. That is, the conversion of luminous energy into electricity.

Now, this photoelectric phenomenon showed that the interaction between luminous waves and matter connected more with the frequency of radiation rather than its intensity.

This conclusion introduces something that was, until then, strange to a physics that had only studied mere changes in position, more precisely, local movement.

Of course, Maxwell's electromagnetism had already denounced that the Newtonian philosophy, or Newton's mechanical attempt to explain all phenomena, would encounter great obstacles ahead. As I said before, during all of the 19th century there were numerous attempts to find a medium that was described by Newtonian mechanics and that could support electromagnetic waves. Thus, they tried to integrate those waves in the general picture of the Newtonian mechanics. We now know these attempts have been fruitless. No medium whose behaviour could be described by the Newtonian mechanics, such as fluids, such as air or water, could act as a support for those waves.

- Can we call it a scientific revolution? – Lucius asked.

Argus replied:

- Not one with the dimensions of the 17th century revolution, no! That one represented, as we have seen before, a huge leap towards a new understanding of the world, towards a new epistemology, towards modern science. With it, mankind earned some trust in its ability to understand the Great Book. This Book is permanently open before our eyes, just like Galileo claimed. But do not forget that in this revolution the only change one dared trying to describe was the simple change in position. *Devir,* change, birth, ageing, in short, movement in the broad sense the Greeks ascribed to this word, wasn't even addressed. What Galileo dared to make intelligible, that is to say, what he managed to mathematically describe, was local movement, a mere change in the position of materials bodies, whose only significant feature was that they had mass, a concept which was later introduced by Newton. This *Devir* that men were able to mathematically describe was not movement in its whole. To reduce the studied object to local movement and being able to mathematically describe it, that was the greatest deed of Newtonian mechanics.

- Why do you speak of this again? – asked Lucius.

- Let me continue - asked Argus who carried on:

- Einstein, with his explanation regarding the photoelectric effect, had given another step in the slow but already long process whose beginning was based upon the observation that the emission and absorption of electromagnetic waves by matter would prove that each element could only absorb electromagnetic waves with certain wavelengths.

During the end of the 19th century scientists had studied the electromagnetic radiation characteristics that matter could emit or absorb. The most studied element was hydrogen. This was due to the fact of it being the most simple of all elements. Hydrogen emits radiation both on the visible side and radiation with wavelengths not detected by our eyes. It was Balmer, while studying the radiation emitted and absorbed by hydrogen in the visible side, who managed to create in 1895 an empirical rule aimed to calculate the several wavelengths of that same radiation. Others followed, such as Paschen's (1908), Lyman's (1906-1914), Brackett (1922) and Pfund (1924), that is, a complete "cartography" of wavelengths the hydrogen atom could emit or absorb. For all other elements and molecules there is a similar situation. When Balmer and Paschen's series were established there was no theoretical frame in which they could integrate into. They were empirical formulas. However, Lyman's series started being built under the same conditions, but in 1914, when it was finally completed, the situation had changed.

We can still recall a whole set of experiments made in Manchester, at the Rutherford laboratory, that became quite important. I am talking about the experiments where positively charged particles were projected against a very thin golden sheet. One observed that most of them did not suffer any detour. The few that did detoured were as if the atoms' positive charge that constituted the used sheet was concentrated in a space area much inferior to the one that was up until then considered to be the atoms' dimensions. That dimension had been underestimated by the kinetic theory of gases and by the statistical physics.

It was after the performance of these experiments that Niels Bohr, in 1913, who was working at the Rutherford laboratory at that date, elaborated an atomic model. Another model amongst others that intended to explain the peculiarities of the emission and absorption of electromagnetic waves by matter and that were in accordance with these new experiments. In those models atom was considered as a tiny "planetary system" that, beyond those positive charges, would possess the overwhelming majority of the atom's mass. The electrons would rotate around the nucleus with much less mass and with a negative electrical charge. The force responsible for the electrons' attraction would be essentially electromagnetic given the gravitational force exerted between the nucleus and the electrons is insignificant. It was a model similar to the solar system, in which the attraction force was electromagnetic and not gravitational.

Besides that and this is where Bohr's model differs from the previous ones, he postulated that electrons could not occupy any orbit in an arbitrary way. Only a small number of orbits were accessible to electrons. The emission of radiation would occur when an electron would pass from an orbit with a greater energy to an orbit with less energy. The energy difference between those two orbits would have to be a multiple of an energy quantum, that is, photon energy. The energy correspondent to each one of those orbits would be calculated in accordance with classical physics. When an atom absorbed energy, that would correspond to the passage of an electron of an orbit with greater energy into an orbit with less energy. This atom model would manage to take on the characteristics of the so called emission and absorption spectrums. It was now "understood" why frequencies or energies absorbed by an atom were similar to the frequencies or energies it could emit.

But there was a problem left, and it was not a small one! Classical physics showed that an electrical charge suffering acceleration would radiate energy. Therefore, while describing orbits around the nucleus electrons were being accelerated due to its speed not being constant. Even if the electrons' orbit was circular and angular speed was constant, that is, if they described equal angles within equal periods of time, speed would constantly change direction due to the existence of a force attracting electrons to the nucleus. A charge would not suffer acceleration in case its movement was straight and uniform, which was not the case. Since charges, according to classical physics, would radiate energy, they would inevitably lose speed, which would inexorably make them fall into the nucleus. This would cause the atom to collapse. This entirely classical model did not allow us to understand the atom's stability.

This was precisely why Bohr introduced an *ad hoc* hypothesis when he claimed that if a nucleus was connected to certain orbits, the electron would not radiate energy.

- As far as I know, that model was hugely successful – interrupted Lucius. - I, being a layman, know that one is the atomic model accepted nowadays, roughly speaking.

- It is – Argus continued. – That is what people minimally informed believe, however, I regret to disappoint you, that is not our present conception of the atom. Quantum mechanics came to radically change that conception.

- But tell me then, which is the atomic model presently accepted? – Lucius inquired, intrigued.

- To answer your question we must proceed slowly – said Argus, continuing:

- In spite of the enormous conceptual hardships it faced, since it accepted and rejected classical physics as it pleased, Bohr's atomic model had, as Lucius pointed out, a huge success. But, as empirical knowledge progressed more difficulties came along, in such a way that, as soon as 1924, there was a great dissatisfaction towards the conception of such a model.

Afterwards, that initial semi-classical, semi-quantum model is developed, it ends up originating the orthodox quantum mechanics, or Copenhagen's. This theory allows us to determine, with a great deal of precision, the frequencies that had been observed in the case of hydrogen in Balmer, Paschen, Lyman, Brackett and Pfund's series, which I have already told you about. Nowadays, that ability has extended to other elements and molecules. Today, this is not arguable because it was a priceless cognitive achievement. Orthodox quantum mechanics, from an operational point of view, works quite well. It is here that we can state that this is the best theory ever elaborated by man. But, when it comes to its implications in the field of gnoseology, this is the most controversial theory ever built.

- But is it not a paradox? – Lucius asked, surprised.

- It may seem so, but it is not – Argus replied. – Quantum physics works fine in these cases. The major problem of quantum physics resides mainly in the fact that it is a linear theory. A linear theory imposes that what we are able to predict of what we observe when studying a big number of quantum entities, we are also able to predict while observing just a few, or, in a limit situation, a single quantum entity. These last situations are precisely what originated the controversy.

- Could you elaborate on that? – questioned Lucius.

- I will try – Argus agreed. – As I have told you, everything originated in the realization that quantum entities had both corpuscular and wavelike characteristics. Between 1924 and 1927, it all happened very quickly. I will not go further into details, but I can say that the two main scientific research programs were developed in this period. One in Gottingen and another in Vienna.

In Gottingen, they have built a theory based upon the Newtonian mechanics in which classical observables were replaced by more complex mathematical structures, which mathematics called matrixes. On the basis of this scientific research program there was an exclusively corpuscular conception of quantum entities. It is important to underline here that it was within the framework of this program that Heisenberg, early in 1927, came to his famed relations, which, a little inappropriately, were named uncertainty relations.

On the other hand, in Vienna, another scientific research program followed, in which quantum entities were regarded as mere waves. It is also significant that it was within the framework of this scientific research program that Schrödinger came to his famed equation, which was named after him.

Besides, Schrödinger himself showed, in 1926, that the problem's formulation achieved in Gottingen's research program was formally equivalent to his own.

Neils Bohr knew all this by the time Heisenberg looked him up early in 1927 to tell him of his great discovery, that is, his uncertainty relations. As we know, Niels Bohr was very hard on him, saying that what Heisenberg presented him was a mere mathematical construction. All of that lacked physical interpretation. Bohr was fully aware of the fact that one cannot build a theory capable of accounting for the phenomena known until then, without simultaneously considering the wave and corpuscular characteristics that quantum entities seemed to have. That is to say, he was aware that it was necessary to build a theory capable of integrating the wave and corpuscular characteristics of quantum entities. That is what he worked on between February 1927 and August that year.

- Are you saying that Bohr managed to integrate those two concepts, the concept of wave and the concept of corpuscle, in a theory that was capable of describing the experiments' data? – Lucius asked.

- That was Bohr's remarkable deed, which he fulfilled in his own way. That is exactly how he managed to achieve that synthesis that generated the huge controversy that you want us to discuss - Argus replied. – It was in that process that the principle of complementarity, which is the conceptual basis, the metaphysics of the orthodox interpretation of quantum mechanics, emerged.

- But what is the principle of complementarity after all? – inquired Amadeus.

- The most general statement claims that there is a relation of complementarity between a time-spatial description and a causal description of quantum phenomena - Argus, with a hint of provocation, answered, and added:

- The more we wish to describe phenomena in a time and space framework, the less we will be able to establish a causal nexus between those phenomena, and vice-versa: the more we try to establish a causal nexus between phenomena, the less we will be able to describe those phenomena within the framework of space and time.

- But what is the relation between the principle of complementarity with what we have been discussing so far? - asked Lucius, intrigued. - So far, we have been discussing corpuscles and waves. What does that have to do with the time and space concepts, or with causal relations between phenomena?

- It is strange, isn't it? – asked Argus, in order to reply. - But this was the more general statement that Bohr gave to this famous principle which shaped the whole history of physics in the 20th century.

A lot has been argued about the way Bohr succeeded to obtain such an interpretation of the quantum formalism. The official position of the Niles Bohr Institute is that there is only an interpretation possible of the quantum formalism and that Bohr, without a trace of influence, solely through his geniality, was able to find it. This was precisely the position of a scholar in this field, charged by the Niels Bohr Institute with the responsibility of publishing a volume of the *Collected Works* of Niels Bohr, under the title of *Complementarity Beyond Physics*, and which tries to analyze every possible influence Bohr may have had. The responsible for publishing was David Favrholdt, who, in all his articles and in the book he wrote on the subject, has always defended that Bohr was not influenced in obtaining his only possible interpretation of the quantum formalism. I totally disagree with that. This is not true. As I have told you before, there are other interpretations of the quantum formalism which reveal the same ability as Bohr's of agreement with the observed phenomena. I am referring to David Bohm and Louis de Broglie's interpretations.

David Bohm's interpretation of quantum formalism succeeds in obtaining every result Niels Bohr's interpretation does. It cannot, however, predict new experiments in which the results differ from the ones predicted by Niels Bohr's interpretation, or the orthodox interpretation, or the Copenhagen interpretation. Thus, choosing one or the other, is only a question of philosophical taste.

On the contrary, the causal and local interpretation of Louis de Broglie, besides obtaining the same predictive ability, presents other significant arguments. In the general framework of this causal approach, there have been proposals, for several years, regarding experiments that predict results different from the ones Neils Bohr's theory predicts. The existence of these two possible interpretations for the quantum formalism, which I have just mentioned, clearly shows that Bohr's statement of having found the only possible interpretation of quantum formalism is not true.

Besides, due to what we have discussed in the previous journey, it is always reckless to state that a certain vision of the world is the only vision that can be obtained. I can understand that some people have an interest in defending this position. I can understand that some people like it that way and try to convince others of it. But such a position is nothing but a wish. Maybe religious beliefs would enjoy that this was so. They would wish that the vision of our relation with the world adopted from the Copenhagen interpretation was the definitive answer, thus representing the surrendering of science, that is, of the fight to increasingly better understand the world, ourselves and our relation with the world.

- I imagine Bohr was influenced by previous thinkers that lead him to his propose his indeterministic theory – Lucius risked.

- That is a very interesting theme and many authors have already approached it – Argus replied, and continued:

- Some authors have tried to find that influence in Søren Kierkegaard, the Danish philosopher, nowadays considered to be one of the founders of the existentialist movement. It is important to signal the fact that this philosopher was considered by Niels Bohr's father the main responsible for elevating the Danish language to a cultured language. Others have tried to find this influence in William James, the American pragmatic philosopher. Other influences were sought, but the most plausible, I would say the most evident, was the influence of his philosophy teacher in Copenhagen: Harald Høffding.

This influence has been mentioned for a while, but not until the late 80s and early 90s of the 20th century did several works advance the possibility of new arguments to sustain it in a very plausible way. The works of Jan Faye, Danish, showed the invalidity of Harald's influence. Høffding would never have been able to exert such influence over Bohr, since their lines of thought were different. They kept in contact throughout Høffding's whole life, even if this contact may have diminished from time to time.

The influence of a man of culture, such as Høffding was, had been recognized by Bohr, and not by mere courtesy. I can tell you that in a letter from February 12, 1924, found in Harald Høffding and Émile Meyerson's correspondence, Høffding informs the French philosopher that Niels Bohr had congratulated him on the use of the word *relation* instead of *relativit*y in the title of his essay in Danish on the concept of relation.

Bohr's interest in this book by Høffding is curious, at a time where the crisis of the first atomic theory, or rather the first project for an atomic theory, created by Bohr himself, was clearly established. Acknowledging Bohr's undeniable exactness, it is inadmissible to assume that he would express a view on a book whose content he did not know. In this book, Høffding makes an elongated dissertation on physics and its concepts, which did not leave Bohr indifferent. His comment on the title of this work by Høffding allows us to conclude that he took an interest in his teacher's work at the time, and not only while he was his philosophy student in the University of Copenhagen. It is this very book that has a section related with Bohr's principle of complementarity. Today, I came prepared, and I have it here with me.

On pages 197 and 198 of the 1924 book entitled *Relation as a category*, after disserting about the categories of continuity and discontinuity, a recurrent theme in the philosophy of all times, Høffding stated the following: "*Continuity and discontinuity are co-relatives, which feed each other. They designate different points of view and different operations; the history of science shows how both, one and the other, claim precedence, but in such a way that the fight between them is always reopened. No one has shed a more enlightening light over their relationship as Henri Poincaré, when he said: «This fight shall last for as long as we make science, for as long as mankind shall think, because this fight is due to* two irreconcilable needs *of the human spirit, of which that spirit cannot deprive itself of without ceasing to exist, the need to understand, and we can only understand what is finite, and the need to see, and we cannot see but the extension that is infinite...*»." This sentence that Høffding enthusiastically quotes, making these his own words, can be found in the text entitled *Les Conceptions Nouvelles de la matière*, from the book *Le matérialisme actuel*, on page 67.

As I have said, Høffding is using this sentence by Poincaré in order to make them his own words. Høffding defended that Psychology was the phenomenology of thought and the laws detected in it would inexorably propagate to all levels of functioning of the human thought. All human thought would have to be "*psychologically possible*", according to Høffding. Moreover, he defended the existence of a complementarity relation, in the exact sense that later on Bohr came to introduce in physics, between the two primordial psychological functions, that is to say, to see and to understand. It is in this sense, that he enthusiastically quotes Poincaré.

Høffding himself exports this complementarity relation to philosophy, another level of functioning of the human spirit. Here, inevitably, because it would have to be psychologically possible, there would be a relation of complementarity between the *a* *priori* forms of understanding according to Kant, which he slightly changes, and the *a priori* forms of sensibility. Within the first ones, that is, the categories, he points out the category of causality for having an undeniable significance in the scope of scientific knowledge. The second ones, as we know, are the concepts of space and time. After this, when we read the more general statement that Bohr gave us on the principle of complementarity, we can easily relate it with Høffding's general epistemology. In that statement, Bohr claims that there is a complementarity relation between a causal description and a time-spatial description. The continuity line is far too evident to be neglected.

- To my understanding, that level of functioning of the human thought which corresponds to scientific knowledge would also have to be psychologically possible! - interrupted Amadeus.

- It could not be any different. Bohr's position, after being properly clarified, had to please Høffding – continued Argus. – That is what Høffding intended when he tried to discuss with Bohr the implications of the new physics in the general epistemological framework, which was his own. Høffding was a man of great culture, but he was not a man of science, and he needed Bohr to explain to him the new developments in physics. For that reason, he could never have been the one to extend the notion of complementarity in psychology and philosophy to physics. Bohr was responsible for that.

Some, less perceptive, may ask themselves if it wasn't quantum formalism itself which lead Niels Bohr to introduce the principle of complementarity in physics without any external influence. This is David Favrholdt's position, which I have previously mentioned. But that would narrow down the status of a man that Niels Bohr was. Bohr was not a scientist to be closed inside the framework of problems raised by the physics of that time. Surely, he knew those problems better than anyone, but his concerns were a lot wider. Niels Bohr has earned himself a status in physics that few others have achieved. With a similar status, I could only mention two others: Isaac Newton and James Clerk Maxwell. The three major theories in physics were established by these three men. As you know, I am referring to Newton's mechanics and gravitation, Maxwell's electromagnetism and, of course, Bohr's quantum mechanics. One who is able to construct theories such as these, cannot be focused only on the problems raised by physical phenomena.

- How can you be so sure of that? - Lucius said.

- In Bohr's case, which is what we are interested in, it would be necessary to read every work in which he refers to psychology and biology in order to understand the broad view of his concerns. He tried to extend the principle of complementarity to the domain of biology, but his attempt failed roundly there, as we know. The discovery of DNA defeated it.

It would not be possible for me to refer to all of this here, since we would drift from our dialogue's main purpose, but we may easily find it in his writings and in the works of Lily E. Kay and Jan Faye. However, in order to substantiate the general frame of Bohr's concerns, it is inevitable to quote the interview he gave on the 17^{th} November 1962 to Thomas S. Kuhn, Aage Petersen and Erik Rüdinger. This interview has been profusely quoted before, but it is never too much. We should be grateful to Kuhn for having asked the question which helps us to substantiate the general frame of Bohr's concerns. In that interview, at some point, Bohr confessed that he intended to write a philosophical text while he attended the University at Copenhagen, and Høffding's classes. I am incapable of textually reproducing Bohr's words here, but I can summarize his reasoning. In a slightly confused manner, he told Kuhn and the other interviewers, that while he studied philosophy and Høffding was his teacher he had intended to write something on the problem of the succession of the consciousness state. A problem which falls into the domain of psychology. He had tried to make an analogy between that succession of the consciousness state, which he specifically associated with the problem of free-will, and certain mathematical functions. The explanation became rather confusing: a 77 year-old man remembering an idea of his youth. At one point, Bohr interrupted his speech, faced Kuhn and inquired: "*Do wish to ask any other questions?*" And Kuhn takes the opportunity to ask: "*Yes. How did this kind of problem come to you for the first time? With whom have you spoken of problems like free-will*?" And Niels Bohr answered: *"I do not know. It was my life, in a sense, you know..."* It is important to stand out that the interview was to be continued the following day, but unfortunately that did not happen, since Bohr passed away that night. We may then consider these words as Bohr's last words about these problems.

- But that complements Bohr's confession that the problem of free-will was a central issue in his life! – intervened Lucius. – Is it not that this problem was intrinsically connected with those difficulties we always feel when trying to understand the world? Couldn't that irrational irreducible residue you have been telling us about reside there?

- I very much think so - answered Argus. – I do not find it hard to admit that Bohr's concerns made him the only one capable of interpreting quantum formalism in the way he did. His philosophical and epistemological concerns were what allowed him to glimpse something he considered to be fundamental, and that would always be present in quantum formalism. That was the reason why Bohr believed, more than once, that there was a connection between a given formalism and something that would be the irrational and irreducible residue, which, no matter how hard we tried, we would never be able to overcome. Bohr believed that this formalism finally and definitely traduced the hardships we find while trying to understand the world, scientifically speaking. This was how the irrational and irreducible residue Høffding formulated, through a principle of complementarity, in psychology and philosophy, extended to physics. To Bohr, that principle would now be expressed in a mathematically lucid way. These were his deepest philosophical and epistemological beliefs, which allowed him to find a way of extending the principle of complementarity to physics, and therefore, to science.

What gave Bohr a chance to shape the whole 20th century history of physics, was precisely what I have just mentioned. But I do believe, and I say it one more time, that we will be moving too fast if we intend that a certain theory, and in the case of quantum mechanics we may speak freely of theory, points out limits in our capacity to rationally understand the world.

It is a mistake, so naïve as the mistake 18th century Newtonians made when they claimed the Newtonian physics was a description of the world as it was. I repeat once more that a theory is not, and can never be, THE THEORY. This is a mistake in which, unfortunately, some men of science incur. Forgetting their human condition, they get too much carried away by their deeds.

It is understandable that a theory like quantum mechanics, which is imposed through the grandeur of its formalism, the ability to describe phenomena with great exactitude, and which raises, so evidently, our ability to intervene in the world, leads some to an over enthusiasm, intending it to be more than it actually is. A theory is based upon non provable claims, postulates, which compromise us with a given ontological position. That ontology can only act as a basis for building a formalism that can only intend to describe phenomena at the scale through which we apprehend them.

I remind you once more that the Great Book of Nature is still not completely accessible to us, and I do not know if it will ever be. Even as for the set of phenomena to which we already have access, there is nothing that can ensure us that it is not possible to find a more general and more fertile theoretical frame. Physics, although it has been able to produce three first line major theories, still is, largely, a patchwork quilt.

- You speak of three theories, but in the field of physics, there are more! – Fabrus intervened. – You do not consider thermodynamics a theory?

- Of course it is a theory - replied Argus. – But it does not share the status of the three theories I have mentioned. Statistical physics, to which I would rather refer to as statistical methods in physics, has already reintegrated classical thermodynamics in the general framework of Newtonian physics and in the frame of Maxwell's electromagnetism. Therefore, I would say that thermodynamics is a second line theory, since the metaphysical frame it moves in is the one of classical physics. We could still mention quantum statistics, but even there, it is too evident that the ontological frame in which they move is the one quantum mechanics.

- And what about the special relativity? And what about general relativity? You do not find them to be physical theories? – Fabrus inquired.

- In the sense I am defining them, they are not – Argus answered. – I would dare say those are only theory projects. Like the so called Big Bang "theory" which is no more than a theory project. And also the quantum field theory. Theories they have being trying to build in the domain of the so called high energies physics are also nothing but projects. None of them can be given the status of the three theories I have mentioned. These are first line theories. Thermodynamics is a physical theory, yes, but a second line physical theory, even if it was a first line theory at the time it was created. Wave optics and geometrical optics are second line physical theories, in spite of, just like with thermodynamics, they have been first line theories when they were first created. The same will happen to present day quantum mechanics regarding its formal aspect and its ability to describe what we observe. Today, we can rest assured that it will be so. It will then carry the status of "thermodynamics" of quantum phenomena.

As you may easily understand, I am not a fan of the Popperian falsification. A first line physical theory is not falsifiable. We may only find limits to its applicability, or come to consider it a second line physical theory in the future. A first line physical theory may not be falsifiable because it cannot describe the object itself. It can only describe the phenomena to the scale by which we describe them, and that is the only court where it can be judged. In such a court, it can be condemned for being a fake.

To a first line physical theory, it can never happen the same as to the deferent and epicycle model of pre-Keplerian astronomy. That one cannot be regarded today as a second line physical theory, because it has never been a first line physical theory. It lacked, for example, the requirement of increasing our ability to act in this world. Tools whose functioning was based on that model could never be built from that theory. It was based upon a determined ontological commitment, it had a mathematical basis just like a theory should in order to be considered as such, it described planetary movement with an exactitude which was acceptable at the time, it had a capacity to predict future phenomena, such as eclipses, but it was not capable of predicting non explained phenomena like meteors, or those which were unknown before it was created, nor did it allow, I repeat, to increase our ability to act in the world.

- This is a very interesting subject, but we are drifting a little from the theme which was proposed for this journey – interrupted Amadeus. – We were talking of quantum mechanics and if it was able to substantiate a limit to our capacity of rationally understanding the world.

- All that we have discussed is indissolubly connected – answered Argus, adding:

- The position I am defending does not allow us to accept that conclusion. A physical theory does not describe the noumenon, the object itself, but a limited set of phenomena. To inductively try to conclude that our possibility to rationally understand phenomena has irreversible boundaries set by quantum mechanics is unwise.

- Argus, when you say quantum mechanics is a theory, are you saying it verifies every validation criterion of a scientific theory? – Lucius questioned.

- It could not be in any other way – Argus replied. - It verifies all mentioned criterion. It is based upon an ontological commitment. That commitment claims that the conceptions of corpuscle and wave are irreconcilable needs of the human spirit, which it can never overcome. It is an ontological commitment of a clearly idealistic nature. It is based upon a mathematical support whose semantics is indelibly connected to that ontological commitment. It quantitatively describes the phenomena and we can apply it with remarkable approximation. It also allows for describing phenomena unsuspected until then, such as, for example, the tunnel effect. Finally, it allows us to increase our capacity to act in the world, by allowing us to build new instruments which would be unachievable without it. I could speak of semi-conductors and their miniaturization, which allows having on our desks computers with an information storage and calculation capacity that would have been unimaginable before. I could speak of electronic microscopes that would allow for great progress in other scientific fields, I could also speak of more recent and more powerful tunnel effect microscopes. All this is now accessible to us because quantum mechanics exists. Without it, none of this would be possible.

- You have said that the ontological position that supports quantum mechanics was a position of a clearly idealistic nature. Idealism is, as far as I know, a philosophical attitude that denies the existence of a reality that is independent from the subject. Is this not equivalent to denying an ontology? – Lucius intervened.

- That is not my opinion – Argus replied -, since even extreme idealism like Berkeley's solipsism inevitably takes on an ontological position by denying the existence of noumenon, of reality. When you deny the existence of the object's reality itself according to Kant, you inevitably make an ontological commitment.

The orthodox interpretation of quantum mechanics claims that before the measurement operation there are only potentialities. It defends that before the measurement we cannot speak of the quantum object's reality which we intend to measure. Since orthodox quantum mechanics proclaims to be a complete theory, before the measurement the quantum object does not have the status of being in action. What exists is a mere set of potentialities. In other words, before the measurement there is no noumenon and no phenomena in the Kantian sense, there is only a series of potential states with a certain probability of becoming an action through that future measurement operation.

In this sense, as a last resort, the observer creates reality out from the various possible potential realities, and which could be created by this strange measurement operation.

It is indispensable to outline, once more, that this interpretation is unavoidable when we are dealing with a limited set of quantum objects. When, for example, we make a measurement operation regarding a certain physical property of a single quantum object, such as its velocity, its position or its energy, we are inexorably forced to affirm that, before the measurement, that quantum object does not have a certain velocity, or position or energy. Whether we like it or not, we have to sustain that it has a set of limited or unlimited potential states of velocity, position or energy, to which a determined probability is associated. This is the measurement operation that eventually transforms one of the multiple possible potential states into the present one. In the measurement action, all of those probabilities are instantly reduced to zero, except for the one that corresponds to the observed state, which now assumes a probability which equals unity.

All of these conclusions are, ultimately, a simple consequence of the fact that quantum mechanics is a linear theory. A linear theory tells us, as we have seen, that what is valid for a large set of objects is also valid for a single object. Quantum mechanics describes the statistical behaviour manifested by a huge set of quantum entities with great precision. That is its major trump. The problem emerges when we aim to apply that theory to a single particle. In that case, we are forced to assume an anti-realistic position.

- That is slightly jumbled! – Lucius exclaimed. – You are saying that in each measurement operation we are creating a reality. But that is insane.

- Righteous words. When we claim that quantum mechanics is a complete theory and, thus, it can be applied to the description of measurement operations performed on a single particle, we are inexorably led to affirm that the observed reality is created by the measurement action - added Argus.

- Some went even further. Everett claimed that in every measurement operation one creates as many realities as the existing potential states before the measurement. These are called Everett's Multiple Universes. This way, there would exist, simultaneously, as many observers as there were Universes which matched the potential states before the measurement. But I have to say, this should no longer be considered science, but a mere speculative raving.

I believe Bohr himself would oppose to such delirious. Bohr, when defending that quantum mechanics was a complete theory, refused to talk of what cannot be observed. Such a starting point leads to the fact that before a measurement operation, the quantum object does not have a present state. But potential states. For that reason, one cannot agree either that multiple parallel universes that would have been formed upon performing the measurement, and which could never be measured, are discussed.

Lucius interrupted, reflectively:

- Can it be that the interpretation of Bohr's quantum formalism is permeable to all that kind of reverie? Is there anyone that takes that kind of proposition seriously?

- Everett's proposition cannot be taken too seriously – Argus replied. - However, there are articles being published nowadays about the non separatability of quantum objects that have interacted in the past. Experiments are performed in which they try to point out that characteristic of quantum objects. Many physicists believe that this is so. This is also nothing but a myth. We shall see it further ahead. The explanation of the outcomes of this type of experiment is much simpler starting from the causal and nonlinear scientific research program based upon Louis de Broglie's ideas.

This is, as I hope we may have the opportunity to see ahead, a scientific research program that starts from a realistic philosophical position. But a non naïve realism, which does not confuse the world with what we think of it. The relation between the world and what we think of it is, as I have been saying, a simple analogy relation and not an identity relation. We admit that, at a quantum scale, it is indispensable to assume that the objects we are studying would behave as if they had simultaneously corpuscular and undulating characteristics. On the other hand, it is indispensable that this theory, necessarily a nonlinear theory, leads us to conceive new experiments, new manifestations of those observable characteristics. Moreover, that allows us to conceive new instruments which would not be conceivable without such a non linear theory.

Fabrus decided to intervene:

- Wait a moment, Argus! Differential nonlinear equations have been the object of intense study for over a century. And you know, as well as I do, we have introduced certain potentials that turn linear equations, like Shrödinger's or Dirac's, into nonlinear equations. Some interesting results have been derived from them.

- I believe it is crucial to explain that subject, at least concisely, to our friends who do not share our academic training - interrupted Argus, proceeding:

- Those equations are two alternating postulates of quantum mechanics. You either use one, or the other, according to the quantum object you wish to observe. When we want to predict the result of a measurement performed on a quantum object that has, in relation to us, a small speed relative to the speed of light, and when, you disregard what physicists call the 'spin", we may use Schrödinger's equation. If no such terms are verified, we will be forced to replace Schrödinger's equation by Dirac's. It is upon one or the other, of both these equations, plus the other quantum postulates that quantum formalism is built.

But now to you, my dear Fabrus: the nonlinearity has to be a direct consequence of postulates the new theory. The equation built from a certain conception of quantum objects, of a certain ontological commitment, must be nonlinear to begin with. We cannot hammer down nonlinearity, if you'll pardon the expression, by introducing nonlinear potentials.

Quantum mechanics is a very effective statistical theory to study huge sets of quantum objects where statistical methods can be applicable. The statistical method applied by quantum mechanics is indissolubly connected to Fourier's linear analysis. Bohr's principle of complementarity could never have been achieved if quantum formalism had not been profusely using this mathematical method. But quantum formalism has, inevitably, applicability limits.

The history of physics in the second half of the 20th century is a good example to show the sterility of those methodologies. None of the theory projects that people have tried to develop since then, have managed to go beyond the project stage. None managed to fulfil every criterion that defines a scientific theory.

If we mean to replace the best theory men has been capable of building up to the present day, I cannot get tired of repeating that this is quantum mechanics, we have to start from another ontological conception. This new conception must break with the vision of world derived by Niels Bohr's principle of complementarity. While facing the duality wave-corpuscle in light of the complementarity principle we may introduce all the linear potentialities we want, that we still will not go far. We will still be tied by our hands and feet to a vision of the world which has clearly reached its limits. We will continue being vassals of a theory that can be applied to bigger sets of particles where the linear statistical approximation is licit, but can no longer be applied to studying quantum systems in which such an approximation is invalid.

- All of that is very nicely put, but as you well know, Argus, in science it is necessary to build theories that can prove better than the previous ones - intervened Fabrus. – While the superiority of a theory over the other is not evident, there is no point in wasting time with interesting conversations, which risk being nothing more than that.

- You are right – Argus replied. – In the next journeys I will discuss nothing more than the results which can be obtained, presently, from another, and not naïve, ontology. An ontology based on the ideas of Louis de Broglie.

- We will certainly expect for it to happen quite soon – Lucius concluded.

ENIGMAS AND PARADOXES OF QUANTUM PHYSICS

FOURTH JOURNEY

Late that afternoon, after having crossed practically all of Lisbon in the midst of infernal traffic, I finally headed, on foot, towards the Eternal Return bookshop. I was very interested in the discussion we would have today. After having crossed part of Bairro Alto, I arrived at the bookshop and found that Argus and Fabrus were already there sipping tea. I had a beer and then Amadeus arrived, soon after, Lucius came.

The theme we would continue today was the problem of the wave-corpuscle duality. This subject, as we have seen in previous journeys, is the starting point of Quantum Physics construction.

Argus addressed us to open the dialogue.

- In the early 20th century, researchers came to the conclusion that quantum entities had apparently strange properties! These results, in spite of being inspired by theoretical propositions of the more daring thinkers, came mainly from the domain of experimentation. In order to shed some light over the problem, especially for Lucius and Amadeus, less familiar with such subjects, I will begin with the problem of light.

Late in the 19th century, physicists were studying the problem of the blackbody. The blackbody is an ideal concept. It is, by definition, a body which absorbs all radiation that falls upon it. To say that the blackbody absorbs all radiation that falls upon it is equivalent to say that it does not reflect any of the radiation that falls upon it. The blackbody, by not reflecting any radiation, allowed for the study of radiation issued by a body, without confusing this with reflected radiation. This ideal blackbody, in practise, can be made, approximately, with a device in the shape of a sphere-like oven, with a small hole through where we make radiation pass. It was Bohr's physics teacher in the University of Copenhagen who had the idea for the first time. To understand how interaction between radiation and matter is performed would allow, and it did, among other things, to determine the temperature of the stars. The experimenters, from the emission and absorption records of certain bodies, had established the related empirical curves.

It was now a matter of finding the theoretical expressions which allowed the explanation and derivation of such experimental results. I mean, to find the mathematical formula that would describe such empirical curves. Among other researchers who dedicated themselves to this subject was Max Planck, who, with some effort, published 20 memories on the subject, and presented a proposal to solve this problem in 1900. In spite of having found the solution, if we can actually call solution to the proposal, Planck was not satisfied with his work. Such discontent derived from the fact that, in order to obtain an agreement with experimental data, he had the need to introduce a hypothesis he did not find satisfying at all. It was the *ad hoc* hypothesis, introduced in a perfectly arbitrary way, that the emission and absorption of light was discretely processed.

- Don't tell me he meant that the energy exchange between radiation and matter is made stealthily? - Lucius asked, intrigued.

Argus smiled and explained:

- In this case, the term “discrete” does not mean stealth. When we say that a certain grandeur is discrete, in this case the energy exchanged between radiation and matter, we mean that it happens discontinuously, that it is performed in leaps. This hypothesis goes against everything that was thought of at the time in the domain of physics, namely against Maxwell's electromagnetic theory, which was firmly established at the time. In this theory, the energy associated to radiation was related to the wave’s amplitude rather than its frequency. Up until then, the exchange of energy between radiation and matter was thought to vary continuously. Now, against anything that could be expected, energy exchanges between luminous waves and matter, and radiation in general, instead of being continuously processed, were made discontinuously. In fact, everything happened as if these energy exchanges were made by packs of light, a jargon expression. Radiation energy, which until then people thought could only depend on wave’s intensity, was now depending on its frequency, that is to say, in a more popular language, its colour. Planck’s formula that states such a relation says that exactly: radiation energy is proportional to its frequency. This proportionality constant was later, and rather justly, called Planck’s constant.

Argus stopped for an instant, drank a little tea and proceeded:

- On the other hand, recalling what I have said before, certain experiments performed by Hertz on the photoelectric effect also led to quite awkward conclusions. The so called photoelectric effect, as I told you before, is no more than the transformation of luminous energy into electric energy.

As Lucius and Amadeus surely know, this photoelectric effect has, presently, huge practical applications. It has many uses, from simple solar energy wrist watches to major industrial production panels of photoelectric energy.

As I have previously said, while discussing this effect, the conclusion drawn from the experiments is that the photoelectric effect mainly depends on the colour of light, that is to say, in a more technical language, radiation frequency. After some hesitation, Einstein came to defend, in 1905, Planck’s hypothesis that radiation must have a discrete nature. Thus, light would be formed by grains or packs, which we nowadays call photons. This hypothesis would acquire citizenship when Niels Bohr created his model, semi-classic, semi-quantum, to explain the atom’s stability. This is how the first brick was laid for the quantum physics’ building. This brick, upon which the whole building of conceptual and formal quantum mechanics is erected, states that energy is proportional to frequency. In this context, it means that speaking of energy or of frequency is equivalent.

- You had already told us that was the step taken by Einstein - interrupted Lucius, and continued:

- But you have also told us that the next step would have been given by the French physicist… what was his name?

- Louis de Broglie! He was one of the greatest physicists of the 20th century, and he has not been properly recognized, at least not until today - replied Argus. – And even after, having come from a wealthy family, he created the Louis de Broglie Foundation to promote and diffuse his ideas. In my opinion, the board of this foundation has not been promoting those ideas. In some cases, it has even ostracized those who, all around the world try to continue Louis de Broglie's project.

Louis de Broglie was born into a family of strong intellectual motivations, mainly literary and historical ones. His love for science comes from the influence of his older brother, Maurice, who studied X-rays, having established a laboratory for that purpose. Louis de Broglie worked in this laboratory, for some time, which was probably one of the better equipped laboratories of its time. In his PhD thesis, made without any support, he proposed, purely theoretically, an extremely daring idea. This idea consisted in claiming that each material corpuscle, electron, proton, etc., was associated to a wave. That wave would manifest itself in the corpuscle's ability to interfere, to diffract, that is, to manifest something that up until then was only associated with radiation, and not with matter.

Argus stopped again, took another sip of his tea, and proceeded:

- I would like to refer something that can be of interest. Most people are not aware that Louis de Broglie had a hard time having his thesis approved by the University of Paris. Paul Langevin, the person in charge of evaluating the thesis, feeling unsure, reported, amongst others, to Einstein. Einstein, in his answer, told him that the applicant had probably lifted a tip of the "great veil". Likely, due to Einstein's support, or, who knows, for being an aristocrat, or even because his brother Maurice de Broglie had an excellent personal X-ray laboratory, his thesis was finally accepted. It was a far too revolutionary thesis to be peacefully accepted in an academic institution, especially since it came from the isolated initiative of a young researcher.

Let us move on. The attribution, by Einstein, of a corpuscular nature to light, considered a wave until 1905, was based upon empirical data, that is, it went from experiment to theory. Louis de Broglie followed a reverse path to attribute a wave nature to entities which, until 1924, were considered mere corpuscles. Without any empirical evidence, Louis de Broglie conjectured that the wave-corpuscle duality should extend to all physical entities. In order for this daring idea to be accepted, it lacked experimental confirmation. It was necessary to show that each quantum corpuscle was associated to a wave, that is to say, that those corpuscles also had an extensive nature. Thus, it was imperative to perform one or more experiments that showed this was so.

The first experiment was performed by two American physicists connected with applications of a more practical nature and who studied, mainly, the industrial development of thermionic valves. On January 6th 1927, C. J. Davisson and his assistant Germer made a beam of electrons fall upon a nickel crystal and verified that electrons, such as X-rays, diffracted. This was something that up until then was described from the wave nature of the used radiation. As I have told you, to predict an experiment's result is one of the strongest arguments in favour of a theory and also, in this case, of a conjecture. In this case, the issue is not a theory but a fundamental hypothesis to build future quantum mechanics. It was for having advanced the hypothesis that corpuscles are associated to a wave that Louis de Broglie was awarded the Nobel Prize of Physics in 1929.

At this point, Lucius asked for clarification.

- Argus, there is one thing I do not quite understand! According to what you have said, Louis de Broglie's older brother, Maurice, had the best X-rays laboratory of that time. You even said that his younger brother, Louis, had worked there. If this is so, how do you explain that the experiments necessary to prove Louis de Broglie's theory were not made there? Why did Maurice de Broglie decide not to perform the experiments necessary to confirm his brother's hypothesis? If the experiments had been made there, the Nobel Prize would likely be awarded to both brothers. Since this did not happen, only the younger brother, Louis, won the prize.

Argus answered this question, a bit disgruntled.

- That is an interesting question that I have made myself a few times. However, so far, I have not found a satisfying answer...

Let us return to our subject. As I have mentioned, the foundation stones were laid, upon which the building of quantum physics would rise. In fact, what the experimental evidence showed was that, at the quantum level, the location and the extension where indissolubly associated, while in classical physics, one thing was a localized system, a material particle, even if gifted with physical dimensions, and another thing was an extensive system. We can say that a stone, a pebble, for example, occupies a given position. Such information is relevant. However, we cannot say that a fluid, water, for example, is at a certain point. In this case, that information would be of little or no use at all.

At the level of our macroscopic description it becomes relatively easy to distinguish a corpuscle, a local system, from an extensive system, a wave. However, when it comes to knowing if light or an electron has or not an extensive or local nature, it is another story. It gets more complicated because, in this case, we have no direct access to such entities. Only indirectly, through experiments that have been prepared for that purpose, we can authenticate those characteristics.

Let us see which are the fundamental characteristics that will allow us to unequivocally distinguish an extensive system from a local system, that is to say, to distinguish a wave from a corpuscle.

Let us consider, firstly, the process which allows us to know if a given entity has a local or corpuscular nature.

Argus takes a sheet of paper and draws the following sketch

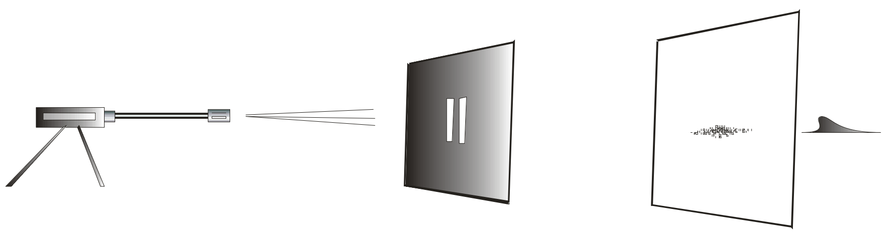


Fig. J4. 1 - Experiment of the two slits with macroscopic projectiles.

Then, he tells us:

- A source of projectiles, a machinegun, emits at a constant rate. In front I have placed a shield with two slits. A target detector records the projectiles' arrival.

So, in this drawing (Fig. J4.1) there is a machinegun firing bullets, macroscopic particles, at a slow and constant rhythm. Facing this source of projectiles we have a shield with two equal slits, S_1 and S_2, through which the bullets must pass (the left slit was named S_1 and the right slit S_2). Further ahead, we have a target where the impact of bullets passing through the slits is detected. Let us now suppose that one of these slits,

S_1, is covered, while the other one remains open. In such conditions, only the projectiles coming from the open slit are able to reach the target detector. After some time, let us say half an hour, we will find in the target detector a distribution of impacts from projectiles that has a shape approximate to a bell, centred in the direction that joins the slit called S_2 to the exit of the machineguns' barrel. This distribution is quite common since it describes a great number of similar events and is statistically called normal curve or Gaussian curve. If we now reverse the situation covering slit S_2 and uncovering slit S_1, after the same time interval, we will obtain a Gaussian distribution fully equal to the previous one. The only difference is that it is now slightly dislocated with respect to the previous one, because it is centred in the direction that joins the slit S_1 with the gun barrel's exit.

The issue that now arises is to predict the distribution of the projectiles' impacts observed in the target detector when both holes are simultaneously open during the same time interval.

Turning to Amadeus, he inquires: - What do you think, in this case, will be the distribution of impacts in the target detector?

Amadeus replied, rather pleased:

-It seems to me the answer is quite obvious! Sometimes bullets go through one slit, other times they go through the other one. Thus, after half an hour, for example, we shall observe an impact distribution fully equal to the one we would observe if the slits were opened alternately. Am I right or not?

- You provided the correct answer! — Argus replied. — In fact, that is what we can observe in such an experiment when using macroscopic particles, in this case, bullets. Thus, we verify that the result of the experiment, the distribution of the bullet's impacts on the target detector, is independent from performing the experiment with two simultaneously uncovered slits, or with one alternately closed.

The conclusion to be drawn from such experimental results is that this is a local phenomenon, or a corpuscular one, since the final distribution does not depend on the fact that the experiment is being performed with the slits opened simultaneously or alternately. Thus, we conclude that the entities emitted by the source, bullets, have locality attributes being, therefore, corpuscules.

Fabrus, who had been silent until then, decided to intervene:

- With this expedite process, Argus managed to create a simple and safe criterion to define the local properties of a determined physical entity, macroscopic or microscopic.

-Thank you - said Argus, and proceeded:

-Let us now find out how we can find an equally simple criterion to characterize an extensive system. We will also consider a classical situation now, in a way, similar to the previous one.

And he starts drawing Fig. J4.2. Although Argus draws well, the drawings I am presenting, in these dialogues, are improved versions of his drawings. I have made them myself, on the computer, with the aid of a CAD program, starting from the drawings Argus and Fabrus made. However, you may rest assured that I have tried to be as faithful as possible to the authors' idea.

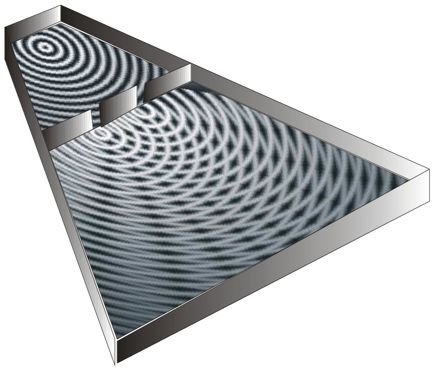


Fig. J4.2 – Interference of two waves.

When he finished the drawing, Argus began to speak:

— As we may observe, this sketch represents a receptacle containing water, the surface is initially at rest. With an object, some sort of buoy, for example, we create a disturbance on the water's surface in the centre of the circle represented above in the drawing. This disturbance produces a circular wave that propagates on the surface of the water, reaching the shield with two slits. When it meets that shield with two slits, this initial wave will produce two waves which, naturally, will also propagate. In their propagation, these waves will expand, and overlap. This overlapping originates an interferential shaped image in the detection zone.

This image of interferences derives from the fact that, in certain regions of space, both waves would oscillate in the same way. In this case, both oscillations strengthen each other originating an absolute maximum if they both oscillate upwards or downwards, and an absolute minimum if one oscillates upwards, and the other downwards. In technical language, one says that the two waves within that region are in phase when they originate to a maximum.

The concept of phase we are introducing corresponds to a somewhat complex notion, from the physics' point of view. However, aided by a simple example, using harmonic waves, we may learn something about what this means. Thus, we shall consider two harmonic waves which overlap – and he starts drawing the following sketch:

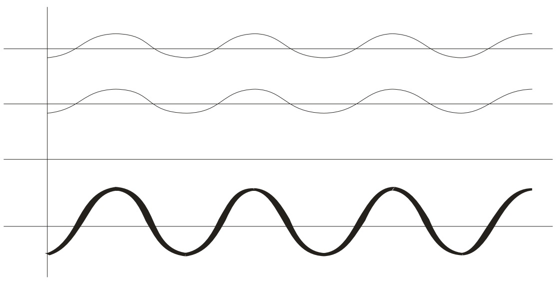


Fig. J4.3 – Overlapping of two waves with the same phase. Waves in-phase.

In this case, both waves have the same phase value, that is to say, at the origin, the vertical line, they have the same value. This type of overlapping in which both waves have the same phase is also commonly known as overlapping in-phase. Thus, their sum, represented below in bold, originates a strengthened wave which corresponds to a doubling of the previous ones.

If, at some other region, waves have opposite phases, oscillations are such that one tends to elevate the water level and the other one tries to lower it. Both actions end up annulling the other, thus keeping the water level unchanged at that point - Argus starts another drawing:

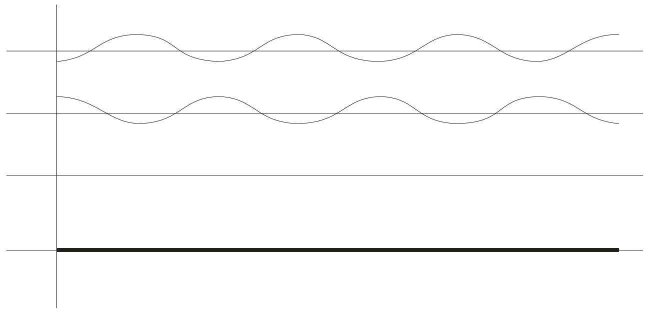


Fig. J4.4 – Overlapping of two waves in phase opposition.

As we can see in the drawing – and he points to Fig. J4.4 -, now both waves, at the origin, do not have the same value. As it happens, they do share an equal value but have opposite signals. Thus, their sum originates a null wave. In this case, one commonly says that the waves are in phase opposition. Naturally, between these extreme situations all remaining cases are possible.

What will happen if we now cover one of the slits? The initial wave, coming from a source, when arriving at the shield will originate one single wave. This wave will propagate without originating any interference. This happens, obviously, because in order for an interference to exist, the joint action of at least two waves is required. In this case, the experimental results, the distribution observed in the detection region depend significantly on the fact that the experiment is performed with both slits uncovered simultaneously, or with only one of them uncovered alternately.

In case both slits are simultaneously uncovered, we will observe an image of interferences due to the two waves overlapping. If there is only one slit open alternately, we will not observe interference.

At this point, Lucius decided to intervene:

- It all looks very clear to me. What we observe, when it comes to water, when both slits are open simultaneously is a lot different from what we observe when we open only one slit at a time. On the other hand, since bullets are, in their nature, indivisible, what we observe when both slits are open is precisely the same as we observe with one slit at a time.

- That is precisely it! - replied Argus. - Moreover, that allows us to establish a criterion which makes it possible for us to realize, in a particularly simple way, and I shall say, even in an elegant way, if the entity in study, be it microscopic or macroscopic, has a local or corpuscular nature; or if, on the other hand, it has an extensive or wave nature.

Let us see if you agree with this criterion:

a) If the observed distribution, in the detection region, does not depend on both slits being open simultaneously or not, then we have a local or corpuscular phenomenon;

b) If the observed distribution depends on the experiment being made with alternately or simultaneously opened slits, then we are facing and extensive or undulating phenomenon.

- I absolutely agree with you - answered Lucius.

- I am glad - replied Argus. – The experiments I have mentioned so far have been conceived with macroscopic entities. Let us see what happens when this very same experiment, the two slits or two holes' experiment, is performed with quantum entities.

At this point, Argus starts drawing another Fig. on paper (Fig. J4.5), which again, I draw more thoroughly:

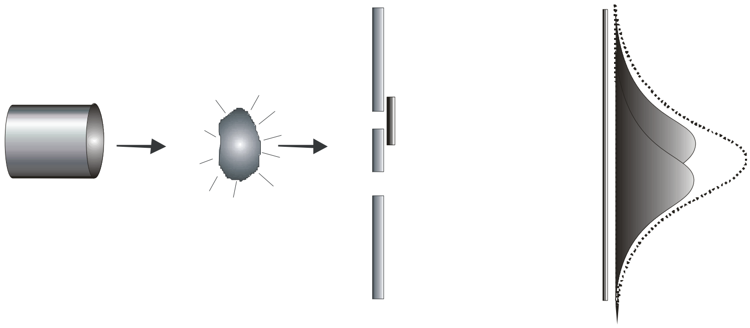


Fig. J4.5 – Two slit' experiment performed with electrons, with one slit open and one closed alternately.

After drawing, he proceeds:

— By the way, and only for information purposes, I wish to refer that these kind of experiments have been made with practically all quantum systems. Photons, electrons, neutrons, alpha particles, and even with quite large systems such as, calcium atoms and others.

In our case, and to settle our ideas, let us suppose that we have an electron source emitting them at a slow rhythm, so that we can only find one single electron at a time in the experimental device.

This requirement of having only a single quantum entity, for each instant, is fundamental. If we did not take this precaution it could occur that, at some points, we would have more than one particle in the experimental device. In such a case, they could eventually interact among themselves, thus producing a false final result.

In the required conditions, when one of the slits is uncovered and the other one is covered, we shall observe on the target detector electrons arriving according to a continuous Gaussian partition, centred in one slit or the other, according to which slit is open. This is what Fig. J4.3 represents.

The problem that now arises is the following:

What will happen when the experiment is made with both slits open simultaneously?

In situations like this, to answer correctly, it is best to let practise do the talking, that is to say, the experiment. And what do the experiments performed tell us about this matter?

All experiments performed with quantum systems so far have always as a final result an interferential distribution, as shown in this drawing (Fig. J4.6 on the next page).

- How is it then possible to explain this experimental result? – Argus asked himself, answering:

- If in the experimental device we only find one single electron at a time, being *a priori* ruled out the hypothesis that we might sometimes have two electrons passing, one through each slit.

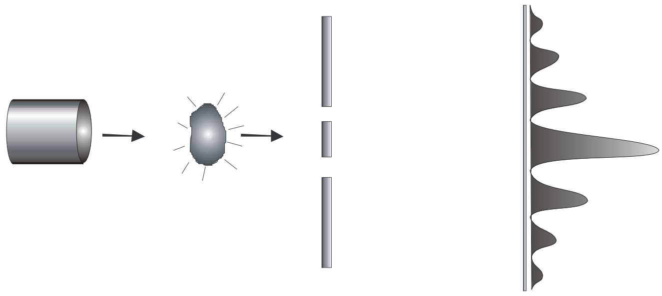


Fig. J4.6 — Two slit experiment performed with electrons with the slits open.

If we were to reason in classical terms, considering the electron a corpuscle, we would be tempted to claim that sometimes the electron would have passed through one slit and sometimes through the other. In this case, it would not be possible to explain the observed interferential distribution since, as we have seen before, for an interference to occur at least two waves are required. Thus, whatever the nature of the quantum entity we call an electron may be, it had to pass, one way or the other, through both slits simultaneously.

So, this experiment leads us to two apparently contradictory conclusions.

That strange quantum entity, which is the electron, has passed:

A) through one slit *or* the other (since we have one single electron);

B) through one slit *and* the other (since it originated an figure of interferences).

Once more, Argus takes the pen in order to draw on a sheet of paper – I see it now – a provocative drawing.

- This drawing (Fig. J4.7) – Argus adds – tries to humorously illustrate this strange situation.

This drawing seeks to point out the fact that the quantum entity, in this case mockingly represented by a cat, has to simultaneously pass through both sides of the obstacle, we do not know how, and materialize again as a single entity after passing through that obstacle.

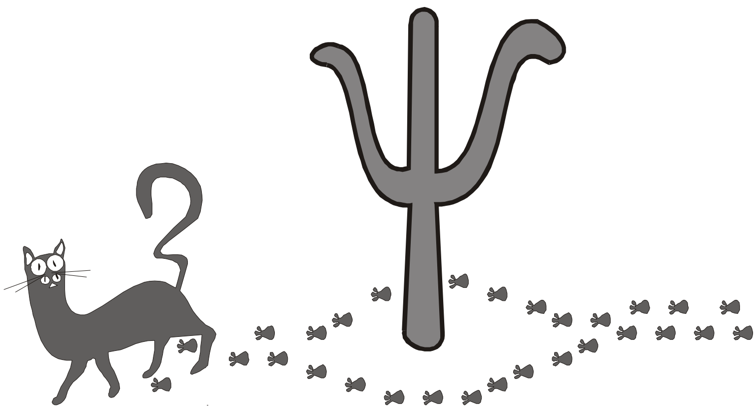


Fig. J4. 7 - Burlesque illustration of the wave-corpuscle duality problem.

We are, as far as we can see, before what seems to be a logical impasse!

The electron has to, simultaneously, pass and not pass through both slits. How did physicists in the early 20th century solve this problem, the fundamental problem of the wave-corpuscle duality? - He asked again, not asking anyone in particular.

- Argus! I would like to be the one explaining how this apparent contradiction can be solved in a fully satisfactory manner — intervened Fabrus.

- I agree, Fabrus. In fact, I believe you are the right person to do so – Argus agreed.

Fabrus smiled and proceeded:

- Niels Bohr, the most important physicist of the 20th century, found the solution for this problem. Argus himself told us that, just like the 18th century is considered the century of Newton within physics' domain, the 20th century shall be remembered as the century of Bohr. And this is because Niels Bohr found the solution to harmonize local and extensive characters shown by quantum systems. He found this between February and September 1927. The solution he obtained was, and still is, a revolutionary solution. He presented it in public for the first time in the Volta Congress. This meeting took place at Lake Como, in Italy, in September of that year in 1927. Before an assembly formed by the most eminent physicists of the time, Bohr explained how this problem could, and should, be solved.

In such conditions, in order to solve the apparently logic contradiction of the quantum entity being able to pass and not pass simultaneously through both slits, a contradiction caused by the wave-corpuscles duality, it became necessary to rethink the way in which our interaction with the world is manifested. This interaction is absolutely necessary, either as a basic need of survival in the world, or to achieve the goal of understanding it, which, like I said, is indissolubly associated with the first. We are handling a fundamental problem, which philosophers have encountered for ages. Thus, it is possible for us to foresee the possibility of finally glimpsing the cause of the hardships we always feel when trying to understand the world in terms of problems deriving from the study of quantum objects. This is where Bohr found an open door to introduce the principle of complementarity which completely reshaped 20th century physics.

The principle of complementarity imposes a limit derived from the characteristics of how we relate to world. Like Bohr claimed at that conference, the more we want to describe a quantum entity using the wave concept, the less we will be able to describe it as a corpuscle. The more we want to describe a quantum entity as a corpuscle, the less we will be able to describe it as a wave. Or, going even further, Bohr would state that it is impossible for us to causally describe the observed phenomena simultaneously in space and in time. The more an aspect becomes clear, the more another aspect will fade.

Here, I agree with Argus when he said that Høffding may have exercised some influence on Bohr. If Høffding enthusiastically applauded Poincaré when he spoke of the *two irreconcilable needs*, which were seeing and understanding, then we realize the synchrony between his view and Bohr's view. Høffding established a complementarity relation, Bohr-like and Høffding-like, between the *a priori* forms of Kant's sensibility, that is to say, the concepts of space and time, and the *a priori* forms of Kant's understanding, which are the categories. They were both handling the fundamental problem of knowledge. What is to know? And they both came to quite similar conclusions. The only difference between their lines of thought was that one regarded himself a man of philosophy, and the other a man of science.

Bohr succeeded in importing a pre-existent philosophical position into physics, giving quantum entities a dual nature: they either manifest themselves as waves, as extensive systems, or they manifest themselves as corpuscles, that is to say, localized entities. These two complementary aspects never manifest themselves completely and simultaneously. The more an aspect looks clear, the more the other will fade, and vice-versa. So, according to the experiment's conditions, the particle is either showing corpuscular characteristics, or wave properties, which manifest through its ability to produce interferential image.

This all leads to conclude that quantum systems, or better still, systems described through quantum mechanics, cannot be given a real and objective existence, in the sense that they do not depend on the subject. A measurement action is, in its essence, the result of a complex interaction between the subject and the object, mediated by the measuring device. It is in this measuring act that the hardships we have always faced when trying to understand our surroundings and ourselves.

If we desire to be thorough when teaching quantum formalism, we will have to point out this situation, because if we don't, we will not be teaching our students the deepest contents of the principle of complementarity, which is a basilar element of the Bohrean interpretation of quantum formalism. The way the subject chooses his form of interaction with the object through the measuring device imposes, to the subject himself, his apprehension of the quantum object, which is sometimes localized, sometimes extensive. This does not tell us that the object can be extensive or localized, it just tells us that both concepts, local and extensive, discontinuous or continuous, correspond to two irreconcilable needs of the human thought, from which it cannot be deprived of, under penalty of ceasing to exist.

Thus, let us see how the mystery of the two slits can be explained, through this new physics that expressly rejects the obsolete vision of space and time and causality concepts of classical physics.

Fabrus picked up a pencil and drew again the two slit' experiment in a sheet of paper. I am representing it here once more (Fig. J4.8) in greater detail.

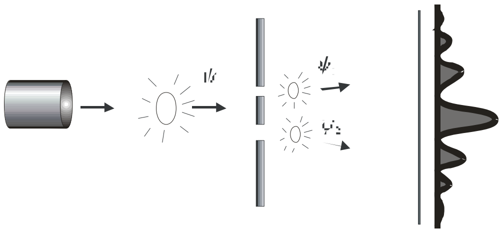


Fig. J4.8 - Niels Bohr's explanation of the two slit' experiment.

He then proceeded:

- In such conditions, the experimental device intends to point out the extensive nature of a quantum entity; in other words, it intends to point out its ability to produce an interferential image. Maintaining both slits open, we allow the quantum entity the possibility of passing simultaneously through both slits. In this case, it originates two waves, but two waves which are not a disturbance of the medium anymore, since they are now understood as mere probability waves. It is when these probability waves overlap that the aforementioned interferential image is, with great exactitude, reproduced.

Thus, we are no longer speaking of a physical wave. We are now speaking of a probability wave. Now, these probability waves are precisely the study object of quantum mechanics.

In this perspective, it makes no sense to speak of position and velocity of the quantum entity, or if it crossed one or both slits. That happens because quantum formalism does not allow us to describe, in space and time, the quantum system's behaviour.

The quantum entity, the electron emitted by the source, not having an objective existence, when arriving at the screen with the two slits manifests its extensive wave nature. In such conditions, it will generate two possibilities, to which there are two associated probabilities, to two potential electrons that will simultaneously cross both slits.

If we place a detector right in front of each slit, one of these probabilities will occur; one of these potential electrons, becomes a phenomenon. That means it generates a “click” in one of the detectors, materializing while crossing, thus earning a status of real existence. Both detectors can never be triggered at the same time. This happens, obviously, because in the experimental device we have only one single electron at a time.

This last experimental circumstance has been chosen to allow us to observe local corpuscular characteristics of that quantum entity which is the electron. If both detectors are removed, we shall replace the experimental circumstance where the local nature of quantum entities can no longer be observed. In that case, the potential quantum entity shall be indirectly observed as an extensive entity, producing an observable interferential distribution. In the detection area, the quantum entity is represented by a total probability extended wave. This total wave derives from the overlapping of the two probability waves. These waves correspond to the electron’s probability of crossing each one of the slits. The total probability wave, deriving from the overlapping of the two waves, has, as we know, an interferential form. Thus, the intensity of this probability wave traduces the probability of localizing the electron in that region of space when we perform the measurement action.

As a consequence, in the areas where this wave’s intensity is null, the electron cannot be observed in a future measurement, since the probability of observing it in those areas is null. On the contrary, in areas where the potential wave’s intensity is at maximum, there is a greater probability of observing the electron in a future measurement action.

Lastly, we can observe the localized quantum entity when detecting a discontinuity on a continuous background. If the considered quantum entity is an electron, we will observe in the detector, which had been clean so far, a discontinuity dot the area where the quantum particle interacted with the detector. When another electron arrives, the effect is precisely the same, but in some other area of the detector. This process is repeated and after a certain period of time the cumulative observation of electrons in the target detector originates a distribution of interferential nature. The longer the experiment lasts, the clearer that interferential distribution becomes stable.

I would like to point out that I have had the opportunity to observe a cinematographic record of this two slits' experiment with electrons, directed by an experimental German group. I can tell you that the effect is indeed curious. At first, we can see a simple dot appearing on the target detector, then another one, and so on. Like raindrops falling. One falls here, the other falls there, apparently at random. However, in time, an interferential image progressively acquires shape until, at last, it completely stabilizes.

As long as we are at it, I would like to request that you look at the drawing more closely. We can verify that there are areas where the electron can never materialize. Such regions correspond to the areas where the potential probability wave's intensity is null. It all happens, in practise, as if the electron "escaped" from the areas where the interference intensity of the two waves is null.

At this point, Amadeus intervened:

- Fabrus, I am quite intrigued by your explanation! In the case of the two slits' experiment it is like there was a kind of teleology which leads the electron to avoid certain areas. Like it had some kind of intelligence, even if rudimental, that made it prefer to bring out a certain point and not another.

Lucius, a bit shocked comments:

- It seems like you are exaggerating Amadeus. In any case I would like to say that I do not like the explanation, the "solution" for the wave-corpuscle dualism problem that Fabrus presented and that according to him corresponds to the one Bohr proposed.

He paused and added:

- So to explain the experimental result of an experiment, in this case of the two slit experiment with electrons, we need to reject the causality and consequently the notions of space and time?! If we reject causality, we open the door for the more extravagant hypothesises, from pseudoscience to a stricter irrationalism. The belief in miracles, that is, in obtaining something without having to pay the price for it, becomes not only possible but also has a scientific justification.

In these conditions, didn't the effort of the human mind to free itself from the darkness, the obscurity of ghostly, magical, mythical explanations, of false gods and other similar powers by trying to understand by himself the world around through reason avail much?

Are we not finally giving up, about two thousand and five hundred years after man started to trust in his own capacity of understanding the world rationally after that important achivement some authors named it "Greek Miracle" to emphasise its exceptionality? I don't think anyone with a bit of culture can deny that our science inherited that indelible Greek tradition.

Basically, our science is no more than an effort to show that whenever we face a certain phenomenon, as complex and strange as it may seem, that phenomenon will always necessarily have a rational explanation. Looking for natural causes for natural phenomena was a legacy from classic Greece. Let us consider, for example, a storm, something that due to its nature has always fascinated and scared men. In a causal interpretation of such a phenomenon we are led to believe that before the storm happened there was necessarily a group of known or unknown circumstances that originated it. No one doubts that for it to rain there has necessarily got to be water! So in last analysis the storm is the result of a group of processes, more or less complex, which have their place in space and time and give as a final result an intense water fall. The old explanation that a storm was the result of the whim of the gods or of another similar entity would be totally unacceptable today. Any event always has an antecedent, a cause that originated it. In my understanding, rejecting this causal relationship between phenomena is the same as abandoning our capacity of understanding the world.

He paused again and looking at Argus questioned him:

- Argus, didn't you say that we could describe the experiment of the two slits without denying the principle of causality? May it be that this strange experiment of electrons can be explained in causal terms? Is it really necessary to reject causality to describe the behaviour of quantum entities? I do not believe that there isn't a possibility of re-establishing causality!

- You are right – answered Argus and continued:

- In fact there is a beautiful and easy causal explanation for the experiment of the two slits with quantum entities. In reality this explanation was given, in the time of the construction of quantum mechanics by Louis de Broglie. But so as to not lose Fabrus' train of thought I think it is best to let him continue his explanation. After he has presented the arguments that he thinks are more convenient for the defence of his non causal and non local thesis, I will demonstrate that, in truth, there is a causal explanation. This explanation is not only more beautiful but also a lot more general as it contains from the formal point of view the interpretation of Niels Bohr as a mere particular case.

Fabrus started his speech again:

- I would like to start by saying that quantum physics, as developed by Niels Bohr and his school known also, as you know, as the School of Copenhagen is probably the biggest theoretical construction that man has built up until now. Its mathematical structuring even being of difficult access by the layman is a building of total rigour and perfection. On the other hand, in terms of precision and efficiency it is unsurpassed at this point in time. No theory built until now compares to it. By the way I would like to know Argus' opinion on my affirmations!

- I totally agree with you – answered Argus and continued:

- In reality, orthodox quantum mechanics or Bohrean quantum mechanics, as it is called by a lot of people, is the best of all the physics theories that man has built so far. Its mathematical structure is quite good, I would not say perfect, as Fabrus affirmed, as there are problems here and there, namely in the question of unequivocal definition of quantum operators associated to classic quantities, and others. On the other hand, its capacity to predict the result of a future experiment, that is, of a future measurement operation about a certain physical property of a quantum object is enormous. In relation to this I am in complete agreement with Fabrus: the efficiency of orthodox quantum mechanics is, without a doubt, amazing. However, we must not forget that this theory is no more than a human construction and because of this it inevitably has weaknesses and limits as I hope to prove later on.

At this time Amadeus intervenes by asking Fabrus:

- I have heard vaguely about a problem that has fascinated me quite a lot but I haven't understood it very well. It is in relation to the cat of Schrödinger. Would it be possible for you to tell me about this?

- With great pleasure – answered Fabrus – This problem was raised, as the name indicates, by Schrödinger. Its purpose was to question the orthodox interpretation of quantum mechanics. It is necessary to say that far from getting to the intended purpose it had the opposite effect. From this conceptual experiment Bohr's vision was cleared and I would even say reinforced. It is a conceptual experiment. A conceptual experiment is one that, in general terms, is not susceptible of being carried out in practice. Its main use is to point out certain consequences of a given theory. In this case, in the experiment of Shrödinger's cat, the aim is to prove that which, in my opinion, should be well known to all who use quantum mechanics. Unfortunately, that does not happen! Most physicists, even those who use and also teach quantum mechanics in universities, continue to try to use the concepts of space and time to explain phenomena in a completely inconsistent and non critical manner.

With the help of Argus he made the following drawing:

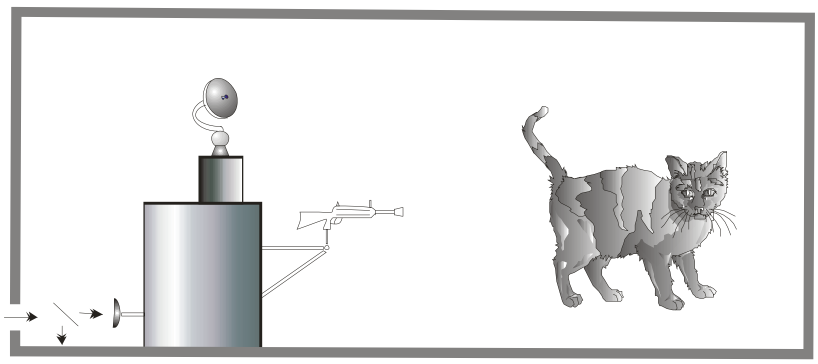


Fig. J.4.9 – Schrödinger's cat.

- This experiment – continued Argus – of a totally conceptual nature basically consists of an armoured and soundproof box in which there is a cat, as shown in the drawing. In this box an orifice was made in which one sole quantum entity can enter, in this case a photon. After entering the orifice this photon finds a semi-mirrored mirror, a semi-mirror, with the feature of being able to reflect or transmit the photon with equal probability. If the photon is reflected it will be absorbed by the walls of the box and nothing will happen. If the photon is transmitted it finds a sensor that detects its presence and at the same time sends a signal to the computer. After receiving the signal the computer will start the search engine, a radar antenna that locates the cat. Once the target is located, the riffle is aimed and goes off automatically, killing the cat. As the box is armoured and soundproof, an observer placed outside the box, has no way of knowing if the shot was fired or not.

Let us then consider the prepared experimental device, with the cat inside and let us start our experiment. For this we inject a photon through the orifice of the box.

He paused and asked:

- Lucius! Are you able to tell me what predictions we can make about the state in which the cat is in before we open the armoured box?

Lucius intrigued, answered:

- Well! If I understood the situation well, one sole photon enters the opening and will hit a semi-mirror. There it has 50% chance of it being reflected and 50% chance of it being transmitted. If it is reflected it will be absorbed by the walls of the box and the experiment ends there. In this case, the rifle does not go off and the cat is still alive. In the case of a photon being transmitted, this will activate the electronic device that in turn activates the computer that puts into action the complex mechanism resulting in the cat's death.

Summarising it: if the photon crosses the semi-mirror, the detector will be activated and the cat will be dead. If the photon is reflected nothing happens and the cat will remain alive. Therefore, it seems to me that the only conclusion is that: the cat is either dead or alive, with a 50% probability for each hypothesis.

In reality we do not know which of the two possibilities happened, only after opening the box can we know which one of the two hypothesises is correct.

- Your answer, Lucius, would be correct in a Universe where wave-corpuscle dualism did not reign, described by the principle of complementarity, which is what happened in pre-quantum physics. Here local and extensive characteristics could be considered as independent properties. At a quantum level that is no longer possible – said Fabrus, continuing:

- Notice that we are considering a quantum entity, a photon of which we did not nor cannot make any observations since, by hypothesis, that is not possible before opening the box. We are therefore from the conceptual point of view in a situation which is in every way similar to the experiment with the two slits. If we did not make any measurement that would tell us that the photon was reflected or transmitted, we have to assume that it was potentially reflected and potentially transmitted, in this case with equal probability. Admitting, like you did, that the photon was reflected or transmitted would be the same as denying the extensive nature of the quantum entity, which is the photon. In these conditions, it would be impossible to explain the appearance of interferences in the case of the two slits' experiment, because as we've seen, for that to be possible it is necessary to take into account the extensive character of the quantum system and consequently assume that it crossed both slits simultaneously. In this case, we have to say that the photon was potentially reflected and transmitted simultaneously. So, the potentially reflected photon corresponds to the potential state of the cat being alive, while the potentially transmitted photon corresponds to the potential state of the cat being dead.

In these conditions, the only solution consistent with the wave-corpuscle dualism is to affirm that before opening the box, the cat is potentially alive and potentially dead, with equal probability for each state. It is the observer who, when opening the box and carrying out the measurement act, actualizes, or makes one of the two potentialities objective. In these conditions and as a last resort the decisive act about the life or death of the cat is up to the observer, as would be expected.

- Ho Fabrus! That is a wonderful conclusion! – exclaims Amadeus excitedly – Now I understand why you said that this experiment had precisely the opposite effect from the one its proponent, Schrödinger, intended it to have. The determining role, the primacy of the observer in the objectivity of reality is thus proven in an unequivocal scientific manner. Now I understand well the scientific motives that led Niels Bohr to reject the notion of causality. As the two existing states, dead cat and live cat, or in terms of photons, photon transmitted and photon reflected cannot simultaneously have a real and objective existence, one then concludes that the objective reality cannot have a real existence but a merely potential existence. Thus, it is the observer who "decides" which of the two possibilities should become real.

- Since we have started on this subject I would like to give another very interesting example, the so called quantum dog – said Fabrus, starting to sketch another drawing:

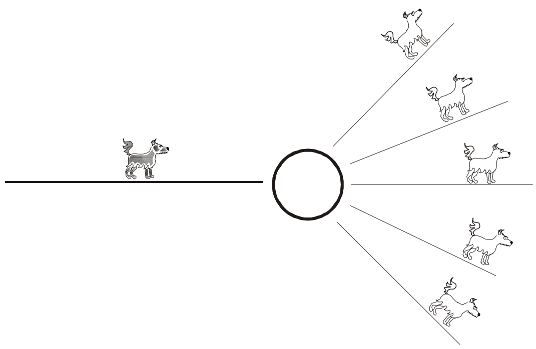


Fig. J4.10 – The quantum dog.

This drawing represents the so called quantum dog, which is nothing more than the burlesque figuration of a quantum particle with mass, for example, a fullerene molecule that, as you know has 60 carbon atoms.

It is a very special dog, a quantum dog. This dog walks along a path feeling very tranquil and suddenly it finds a roundabout with five different paths coming off it.

In a Universe endowed with objective reality the dog could choose one and only one of five possible paths. However, in the Universe of non causal quantum mechanics, the dog being simultaneously extended and localized will have to follow all possible paths simultaneously. Because no dog, with real and objective existence, can follow five paths at the same time, it then follows that the dog loses its physical, objective reality. It then becomes a being without any objective existence, in other words, a potential dog.

In truth it is a strange quantum dog. To guarantee the physical, objective reality of the dog, it would be necessary to say that it followed one of the five possible paths. In this case, we would be in the same situation as the experiment of the two slits to say that the electron had crossed one or another slit. In these conditions we would have to reject the extensive character, the wave character of the quantum systems and thus it would no longer be possible to explain the interferences observed experimentally!

In the Universe of quantum mechanics, whether we want to or not we have to maintain that the quantum dog follows potentially all possible paths at the same time. In these conditions we can no longer speak about its real and objective existence.

When the real dog is detected on one of the paths by the observer, the multiple potentialities, in this case of the five potential dogs, transform themselves into one only single real dog. This transformation, this instantaneous convergence of the multiple potentialities into a single real one is named in more technical language as the collapse, or projection of the wave function. In reality, I only refer to this out of curiosity; it is indeed one of the theory's basic assumptions, the fifth postulate of quantum mechanics. Before measurement, before the observation, the quantum dog was potentially present in all of the possible paths. When measurement took place all of the five potential dogs become one real dog instantaneously.

Fabrus paused for a bit and Lucius made the most of the pause and said:

- Ho Fabrus, I am quite perplexed with your arguments. If not for the guarantee by Argus that is was possible to explain the wave-corpuscle dualism in the conceptual framework of space and time, I would at this moment be completely in despair…

- Now that we are speaking of it – continued Fabrus, drawing something else – and to make things even more interesting, I will mention another experiment, also of a conceptual nature, proposed by a physicist called Renninger.

In the case of the quantum dog and quantum cat, the transformation of the potential multiple states into only one real state was due to a measurable physical interaction, subject to direct and objective register. In the case we are now going to analyse such a situation does not happen. It is an experiment that in scientific literature is called a negative experiment. In this type of experiments the collapse of multiple potentialities into one real state happens without any physical interaction that we can register.

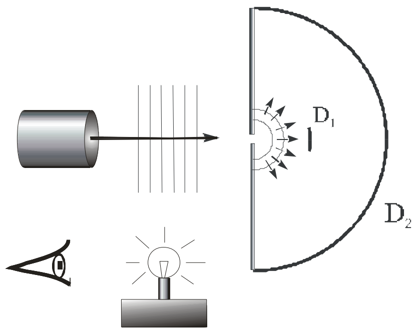


Fig. J4.11 – Renninger's experiment.

In this drawing, (Fig. J4.11), you can see a source for photons that are emitted one by one, which is the norm in this type of situations.

In its journey the photon finds a circular screen with an orifice of very small dimension. After crossing the orifice the photon will manifest its extensive aspect by giving rise to a hemispheric, progressive wave. At the end of time t_1 on its journey this wave finds a small detector D_1, where the photon may eventually be detected. If this detector is activated by the arrival of the photon, an observer placed outside the system will notice the light on. If the photon is not detected by the small detector, it will continue its journey and will later be detected in the great hemispheric detector D_2 which is placed quite far away from the first one.

Before measurement, the photon exists under the form of two potential states, corresponding to the two possible hypothesises. A potential state corresponds to the possibility of it being detected in the small sensor, the other of it being detected in the enormous hemispheric detector. When it goes through the orifice the photon transforms itself, according to what we've seen before, into two potential photons, each corresponding to two possible results.

If the observer sees the light go on it is because the photon was detected by the small detector. In these conditions, the probability of it being detected in the big detector becomes immediately null. The two potential photons, one corresponding to the detection in the small detector, the other in the larger one, converge into one real state.

In this case, as with the other cases previously discussed, the collapse, the transformation of the potential states into one real state, was due to an observable physical interaction and subject to being registered.

He stopped for a little then continued:

- Let us now look at the other possibility. If at the end of the time, let's say t_1, the time necessary for the photon to arrive at the small detector, the light does not go on, what can we conclude? – he asked and turned to Lucius.

- According to the way of thinking that you have been developing the answer is very easy – answered Lucius – However, I must tell you that I do not agree at all with your conclusions. But I must also say that, to be honest, I do not have any argument to refute them. See if I am saying what you want me to? – and continued:

- If the lamp did not turn on, at the end of the time necessary for the photon to reach the detector, we have to conclude that the photon will be later revealed in the enormous hemispheric detector D_2. In this case, the collapse, as you called it, the transformation of the multiple potential states into one real state happens without there being any physical interaction. I believe this is the point you wanted to lead me to, isn't that right?

- As you can see ho Lucius, quantum mechanics is in reality an instrument that is so powerful and so well structured that even those like yourself and I must admit there are many that find themselves in your situation that are led, whether they want to or not, to the same conclusions by the simple use of logic – commented Fabrus with an easy-going smile and continued:

- As you can see, in this special type of measurement the collapse of the multiple potential states or probabilities happened, as Lucius said without there being any physical interaction that could be registered. No interaction was observed, no device registered the smallest alteration but however, the transformation happened.

We thus arrive at the heart of the question: if there was no physical interaction then what is the cause of this collapse? What is the reason for this transformation of the multiple states of potential existence into one single real one? What was the agent that gave rise to such transformation?

At this time, a very excited Amadeus adds:

- If, as we saw, there was no physical interaction that provoked this transformation that led from one Universe of merely potential or probable existence to a real Universe, then the only possible solution is that this cause can only be found outside of physics.

The agent that makes this transformation can only be the observer, but clearly from what we can gather from what Fabrus said not that of the observer as a physical being, but of an observer as a spiritual entity that transcends matter. Thus, when the observer becomes aware that the small detector was not activated, since the light did not turn on, it transforms the two potentialities into one objective reality that corresponds, in this case, to the subsequent detection in the enormous hemispheric sensor.

Concluding: In a last analysis, the transformation of multiple potential worlds into one real and objective world is due to conscience, to the immaterial and transcendent spirit of the observer.

By the way, if you will allow me, I would like to take these ideas that I find extraordinarily deep and far-reaching to their natural consequences – continued Amadeus:

- We observe, in reality, that it is the human observer through his spirit, his conscience, that transforms the possible states, that is, the states with merely potential existence, into one real and objective physical state.

The question I now ask is the following: the real and objective physical world in which we live assuredly forms only one of the possible multiple worlds. I think everyone will agree with this affirmation. As this is the case, who was the Agent that provoked its materialization, that is, the collapse, the transformation of multiple possible worlds into this one in which we live in?

On the other hand, and I believe everyone agrees with me when I state that man is certainly a limited being. In these conditions, assuredly man does not have the possibility to completely observe more than a minute part of one of these possible worlds. So, if he cannot observe more than a simple part of one sole world, what is the possibility of observing a multitude, assuredly enormous, possible worlds? None, I have to say!

If man does not have, as we've seen, any possibility of making a transformation of this magnitude, then who is the Agent that carries it out?

The answer to this question seems obvious to me!

The Agent that makes this magnificent transformation can only be a Superior Entity, a Universal Conscience, in sum, God.

This Universal Observer, in his omniscience, by witnessing all the possible multiple worlds, decides in his omnipotence to make real this world in which we, simple and limited mortals, live in and suffer.

In these conditions, I must say, without a shadow of a doubt that God is, in reality, our only guarantee of objective reality in the world!

Without the Universal Observer, without a Universal Conscience, in one word, without God, the transformation of multiple Universes with merely probable or potential existence into one real Universe, in which we live in, could never happen.

What have you to say about my conclusion ho Fabrus?

A bit hesitantly, he comments:

- In reality, I should say, Amadeus that these conclusions are not entirely new. There is in fact a whole sector of important thinkers who tried and try to establish the bridge between quantum mechanics and religion, namely oriental religions. On the other hand, certain Christian theological currents developed arguments to prove scientifically, if such a thing will ever be possible, the existence of God in very similar terms to the ones you presented.

He pauses and adds:

- However, I as a physicist try to do a more modest work, limiting myself strictly to the field of physics, leaving those complex and transcendent problems to those who are more talented at it.

At this moment, Lucius, slightly downcast asked:

- Ho Fabrus, I feel a bit alarmed after what I have heard. Even so, I would like to ask a question, maybe somewhat naïve. How was it possible to build a scientific theory based on such a strange indeterminist concept of the world? If we reject the primacy of space and time as basic ingredients of our understanding how can we understand our physical world? Moreover, as quantum mechanics, like you yourself said, is a theory with a lot of mathematical coherence and exactness and above all it has enormous prediction power in terms of concrete physical phenomena.

- You asked the right question Lucius. It is precisely in this point that lays the greatness of Niels Bohr as a thinker that raises him to the status, as I had occasion to mention, of the greatest physicist, of the true architect of physics of the 20th century – answered Fabrus. – The answer to this question is in the use of the so called analysis of Fourier. This mathematical technique was developed by Joseph Fourier, an engineer of Napoleon Bonaparte, who accompanied him in his campaign to Egypt. He developed it to resolve the very concrete problem of the transmission and diffusion of heat. Basically, what Fourier demonstrated was that any reasonably well behaved function could be expressed as a sum of sines and cosines, that is, of the harmonic plane waves. Thus, any structure, a particle for example, can be described from a composition, from a sum of harmonic plane waves as shown in the drawing I am about to do:

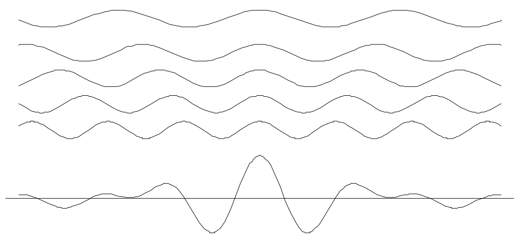


Fig. J4.12 – Sum of plane harmonic waves

In this drawing, as you can see, only five harmonic waves are presented and their sum is at the bottom. You can see that it is possible to build reasonably localized structures even with so few waves. I can guarantee that with the adequate addition of these harmonic waves, that are infinite, both in space and in time, it becomes possible to build, or compose any regular function. These mathematical functions can eventually describe the evolution of structures in space and in time.

For Fourier the analysis that he developed consisted of, as was expected, a simple mathematical instrument, which was extremely useful, but without any physical content. For him and for the physicists of the time, one thing were the abstract mathematical waves that were used for better or worse to describe the physical waves, other thing were the real waves assumed to be real and finite. The so called real physical waves, in this old-fashioned classic perspective would always start in a certain region of space, in a certain instance, and they would necessarily have an end.

So, it is precisely here that Niels Bohr intervenes by attributing a privileged ontological and epistemological status to these waves. From simple mathematical rule of abstract composition of functions, Bohr will promote this analysis to the status of ontology. Thus, he will show that everything is explained, everything is constituted by infinite harmonic plane waves that exist in all space and in all time. This is, after all, the mathematically lucid form to which Bohr was referring to.

In a certain way this attitude corresponds, I must say in truth even if Bohr never mentioned it explicitly, to a true return to the platonic paradigm of perfection and circularity.

As you know, for Plato to reconcile the movements with permanence he considered that the perfect movement is only found in the sphere. This is because when you turn it, the sphere does not change its shape. So even though it is moving the sphere always continues to be, in a certain way, the same as itself. It is a type of still motion, if you can say that.

This platonic paradigm works on the principle that the only perfect movement is the circular movement. Therefore, in Heaven, in the supra-lunar world, a place where harmony and perfection reign all bodies would necessarily have to describe circular and uniform perfect movements.

If the orbits of the planets, a term that in Greek means wandering stars, did not seem circular that would be a mere illusion of our senses. According to that principle of perfection, these orbits must, in a last analysis, result from a judicious combination of perfect circular movements.

The successors of Plato launched themselves into the gigantic task of explaining the harmony and perfection of the skies in terms of this circularity paradigm, as Argus has already mentioned. This effort that lasted several centuries culminated with the monumental book by Claudio Ptolemy, *The Almagest*, an Arabic term which means *The Great Book*.

In this cosmology the celestial bodies have and will always describe perfect circular movements.

Well, as you can see in the drawing I am doing (Fig. J4.13), the projection of a celestial body, while describing a circular, uniform and eternal movement, on an axis, which gives rise to an oscillation, a wave, that is also eternal. This wave is called harmonic, as it results from a perfect and harmonious movement. This movement, which did not have a beginning, will not even have an end.

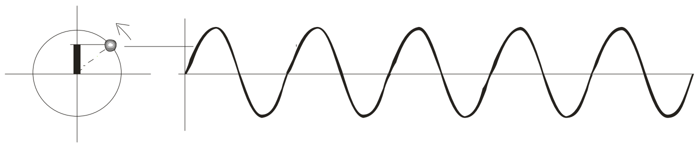


Fig. J4.13 – The projection, on a vertical axis, of a point describing a circular movement is a harmonic wave.

An immediate corollary of this ontology, where as we have seen the primacy is given to the harmonic waves, infinite in space and in time, is that the separability and individuality stop making sense.

In the same way it is immediately concluded that the modification of a given system, its alteration, in a word, its movement, is nothing more than a mere illusion of our senses.

Let us notice this drawing – and he starts to draw:

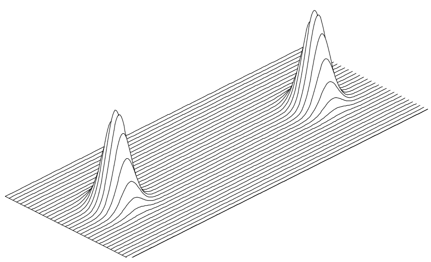


Fig. J4.14 – The sum of a very big number of harmonic waves gives rise to two particles.

In it we can observe two systems, two particles, in this example, relatively separate. At first sight it may seem like the two structures that represent the two particles are completely independent. However, as I will show you, that simplistic conclusion is completely false.

As we observed, in this new ontology of Fourier, whatever the function is, whatever the structure or structures, they are, in last analysis, composed of harmonic plane waves that are infinite in space and time. In the concrete case of the structures representing the two particles, indicated in the drawing, they are composed of the same harmonic waves. Basically, it is a group of infinite harmonic waves that will interfere due to their overlapping. From the interference of all these constituting harmonic plane waves two structures arise in which the overlapping of the waves is not annulled, as we can see in the drawing. In all of the remaining space, the result of the overlapping, that is, the addition of these waves, is null. In this manner, the independence and separability of these two non-null regions is only illusory. In fact, it is the one and same entity.

In these conditions, any alteration in a particle implies, as you can easily see, an alteration in the other one.

Let us see if that is indeed so!

For this to happen, let us consider the following situation. The right hand side particle remains in the same position while the structure of the left hand side particle comes closer to it, as indicated in this drawing:

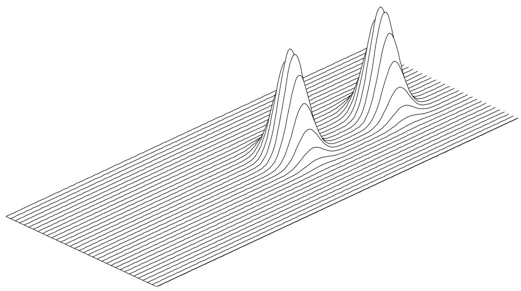


Fig. J4.15 – A particle remains in the same position while the other one comes closer.

In terms of Fourier ontology, where the primacy goes to the harmonic plane waves that exist in all space and all time, the movement, the alteration, of any structure, for example, a particle, is explained in the following way:

As we were able to see, a particle, a given structure, always results from the composition, that is, the sum of many harmonic waves that when interfering give rise to that region in space of non null intensity. If in the following moment, the particle goes and occupies another region in space, then we would be led to say, thinking in archaic, pre-quantum terms, that the particle had moved from one region to another.

However, this obsolete method of thinking is completely misrepresented. In fact, what happens is that the waves that previously interfered constructively in a given region, are now going to interfere constructively in another region in space.

For that to happen it is necessary to change the relations of phase and amplitude of the harmonic plane waves in an adequate manner, in such a way that the constructive interference now occurs in the new region of space.

Saying that a particle is simply located in a given region in space does not make any sense in this new way of thinking. As a particle is intrinsically composed of a group of infinite harmonic waves we would have to conclude, so as to be consistent, that the particle is in fact omnipresent, occupying in truth all the space and all the time.

So, the only conclusion to take is that the movement, the so called separability and individuality of the systems are nothing more than a mere illusion of our senses. It was precisely because of this, as you can see, that the quantum theory rejected preliminarily the deciduous concepts of space and time. In fact, in this modern perspective, any system has in itself all the space and all the time. In these conditions, it can be said that the systems, the particles, are beyond space and time.

If anyone asks you ho Lucius what the centre of an infinite Universe is, what do you answer?

Lucius, feeling like he was stepping on a mine field, answered carefully:

- In an infinite conceptual Universe any point can be considered the centre. By the way, I want to say that I used the term conceptual Universe on purpose, because I do not know if the real Universe is finite or infinite. So for me, an infinite Universe can only have a conceptual existence. Thus, this Universe of an entirely conceptual nature has infinite centres, as many as the points that are part of it. So, a Universe that has infinite centres does not have, in reality, a well defined centre. Or, in other words, it does not have a centre.

Therefore, applying Fabrus's train of thought in relation to the quantum entities, that according to him have all the space and all the time included, that corresponds, in practice, to stating that they are beyond space and time.

- Thank you, I could not say it better – answered Fabrus, and started his speech:

- I want to remind you that before we saw that one of the cornerstones of quantum mechanics was the relation of Planck, which shows that energy is proportional to the frequency of the associated wave. However, we know that in Fourier ontology only one harmonic plane wave has a pure frequency and as such, a well defined frequency. Any non harmonic wave resulting, as we have seen, from the composition of harmonic plane waves, cannot have a well defined frequency. In fact, that wave may have as many frequencies as the harmonic waves that constitute it.

- A new question then arises! If only the harmonic waves do have a well defined frequency and thus, according to the fundamental relation of Planck, a well defined energy, what will then be the energy that a certain particle has?

- The answer to this question is very important and a little delicate.

After a pause, Fabrus continues his speech:

- As we have seen, a reasonably located particle necessarily results from the composition of many harmonic waves, each with its own well defined energy. This means, the quantum particle should have a group of energies, as many as the harmonic waves that constitute it.

In this moment Lucius, who was attentively following Fabrus' explanation, exclaims:

- Fabrus, there is a question here that I do not understand very well! As you have told us, according to the Fourier ontology, where the primacy is given to the infinite harmonic waves in space and in time, a quantum particle, being composed of many of those waves, each with its own energy, should have infinite energies. I think that is what you said, because on that line of thinking, there is no alternative.

However, it seems to me and I am no specialist in this field, that when one makes concrete measurements, one can see that the quantum particles only have one energy, a very well defined one.

How do you explain this contradiction?

- Well, that is precisely the core of the question – answered Fabrus – Before measurement, before the observation, what exists is a group of potential particles, as many as the constituent harmonic plane waves, each with a perfectly defined energy. However, like in the case of the cat or the quantum dog, any of these possibilities, any of these potential particles, has no objective reality. To each harmonic wave, infinite in space and in time, corresponds in reality a particle with a well defined energy. However, this particle is, so to speak, dispersed in all of space and all of time. For that reason it is said that it is a potential particle. When an observation is made, this measurement makes all multiplicity of potential particles, dispersed in all space and in all time to converge into one point. They then transform into one sole real particle and endowed with a perfectly well defined energy. So, before measurement, what quantum mechanics allows us to say is that the particle only exists potentially in various states, each one corresponding to a certain probability of being measured. All that exists is only a group of potentialities, of potential particles, of which one of them can eventually become objective through observation.

- If I understand well what you said – adds Amadeus – it seems that this argument does not bring anything new in relation to the last ones we have seen. If anything it only reinforces our previous conclusions. Once more, we can see that before measurement, undertaken by the observer, or it’s better to say, by the conscience of the observer, quantum mechanics does not describe something that we can define as objective. Let us remember that Bohr defended that quantum mechanics proved in a mathematically lucid way the existence of irrational, irreducible residue that prevents the understanding of the world. Proving the impossibility of achieving the simultaneous description of something that evolves in the framework of space and time according to a causal relation. Once more, and I have to tell you that I am very happy about that, the unequivocal conclusion to be taken is that modern science, quantum mechanics, proves that the Conscience of the Observer, that Agent of an entirely spiritual nature is in last analysis, the guarantee of the existence of an objective reality. In the absence of a Universal Conscience, and therefore of God, there is no chance of transformation of a world of shadows, of virtual particles dispersed in all space and in all time, in sum, of realities only with potential existence, in a sole real world.

Lucius tried to answer but due to the late hour we decided to end the discussion. We arranged that the next discussion time would be dedicated to the causal explanation of the problem of wave-corpuscle dualism.

NONLINEAR QUANTUM PHYSICS

FIFTH JOURNEY

Once more I hurried to arrive at the Eternal Return Library.

In the last discussion, Fabrus had shown, in a very convincing manner, I must say to be truthful, that the only way possible of completely interpreting the wave-corpuscle dualism was in the way Bohr did. The principle of complementarity was the fundamental element of all that interpretation. This means that within quantum formalism we cannot speak about the real existence of something before the measurement. It is the measurement done by the observer that, in last instance, transforms the multiple possibilities or potentialities of existence, into one sole objective and real state.

Now, in the discussion that we would have, Argus would show us how the apparent contradiction raised by the wave-particle dualism could be resolved without any need to renounce the causality and thus reject the existence of an objective reality, independent from the observer. I think you must understand the reason for my expectancy and at the same time my fear. On one hand, I wanted to believe that such a thing was possible, because as I am a practical person I am used to deal with concrete situations in my day-to-day life, I do not have a great natural predisposition to admit that reality is created by me. For instance, that since I see the Moon it was because I myself created it out of nothing! That seems to me to be the first step for us to touch upon things like occultism, esotericism, witchcraft, magic and others, in sum, everything that can be more properly named obscurantism. However, Fabrus' explanations were so complete and convincing that they left me, I have to recognize, very worried. This is because we cannot forget that Bohrean quantum mechanics is, apart from everything else, a great and consistent physics theory.

When I arrived, Lucius and Amadeus were already there as they had come together. I ordered a beer and we started talking, while we were waiting for the other members of our group. Amadeus, being the editor he was, talked about the growing difficulties that this sector was facing due to the fact that people were reading less. This situation was entirely corroborated by Lucius who, apart from having a solid technical and scientific basic education, was also an intellectual of merit and sometimes also a writer.

This café conversation, aimed above all at passing the time, went on until Argus and Fabrus arrived. After the usual greetings and after both of them had ordered a cup of tea, we started our discussion.

As previously arranged, Argus started off:

- On the way here I was thinking about the best way to present my defence on causality.

I think the most consistent way of proceeding and above all the clearest way will be to firstly attack the conceptual nucleus on which all formal structure of Bohrean quantum mechanics rests. As we were able to see with the brilliant intervention of our friend Fabrus, this nucleus is composed by Fourier ontology.

After the famous Solvay Congress of 1927, orthodox quantum mechanics was developed and extended, both from the formal point of view as well as in its application, until it reached the powerful theory it is currently. The basic instrument for this development and consolidation was Fourier analysis, that is, as we saw, non local and non temporal. It is never too much to point out this fundamental characteristic, which is often forgotten by many who use it. On the other hand, I must mention in passing that most physicists of the time did not know, or were even motivated to know, the other types of analysis that already existed. The applications of this non local and non temporal analysis was soon generalized from quantum mechanics to practically every branch of physics and technology. As a paradigmatic example of this migration process we have the case of telecommunications, where not very long ago Fourier analysis reigned omnipotent.

However, in this idyllic panorama of Fourier ontology, more or less implicit in all domains of knowledge, a notable event occurred in the beginning of the 80's of the 20th century. It was the discovery of a new mathematical analysis of local character, named as analysis by wavelets. This local analysis, as we will be able to see, contains the non local and non temporal analysis of Fourier as a particular case.

For the sake of information and above all taking into account the presence of Lucius and Amadeus, I would like to mention the following: Contrarily to what would be expected, this new and very important branch of mathematics did not appear in the "high" dominions of theoretical physics, such as physics of particles, cosmologies and similar, which with great fanfare are in general presented in scientific magazines as the last word of human skill. In reality, these magazines are making a terrible propaganda of science, since all its branches have a relevant role and their relative importance, if indeed it exists, is naturally very difficult to assess. This great discovery occurred in the "common" fields of practical applications. As you surely remember, this discovery process has a certain similarity with the non local and non temporal analysis. This analysis was discovered by Fourier to resolve a very concrete practical situation: the problem of heat diffusion. These and other facts of similar nature, of which the history of science is full, show that in general the most important and fruitful discoveries come from the least expected places. Wanting to plan scientific research until exhaustion was and will always be a task of bureaucrats and sooner or later necessarily doomed to failure. Scientific research is essentially an adventure towards the unknown.

This admirable discovery was due above all to the effort of the physicist Jean Morlet, who worked in the field of Earth sciences. As you know, these scientists are generally known as geophysicists. This geophysicist was then working for an oil company. His work consisted mainly of developing methods that allowed oil havens to be detected more efficiently and economically. The main method used in the studies consisted of seismic analysis in locations considered more convenient by geologists and, after that, study the collected elements. These seismic records were studied later, using the most fashionable mathematical instruments. In this case, as you can imagine, it was the non local and non temporal Fourier analysis.

Well, what Jean Morlet quickly realized was that such a global analysis was not very convenient for what was intended, mainly due to the fact that it led to very strange solutions (this is the least that can be said about it). As we saw in our last discussion, in terms of Fourier ontology any finite impulse (and I must emphasise here that all real physical impulses are necessarily finite) is composed of harmonic plane waves, each with its frequency well defined. As it is known, in the dispersive mediums to each wave with a certain frequency corresponds a characteristic propagation speed. So, each seismic finite impulse, registered by seismographers has not got a well defined speed in this ontology but infinite speeds. The number of these velocities is as many as the harmonic waves necessary for, through summing them, the reproduction of a recorded impulse. Once the components that compose the impulse, the harmonic waves, fill all space and time, everything is possible: inclusively the strangest retroactions in the past, like for example, the case of an action carried out now having a decisive influence on what has already occurred. I hope to discuss with you later a very interesting experience where some people intended for a situation like this to happen.

As I mentioned, in certain cases the use of Fourier ontology leads to such situations that the impulses, the seismic waves, occur before the earthquake has taken place! Sometimes the precursor seismic waves happen before the Earth even exists! Of course, geophysicists, due to the nature of their profession face very concrete practical situations daily that do not relent with certain metaphysical deliriums and speculations. This forces them to be very down to earth. That is why they despise these aberrant solutions that go against good sense and that are nothing more than a simple consequence of the implicit and non critical acceptance of Fourier ontology.

It was precisely to avoid these aberrant situations that Jean Morlet developed his finite analysis, commonly known as local wavelet analysis. His initial work was later developed and formalized, in strict mathematical terms by Grossman, Meyer and many others. This work proceeded to such a degree that the local wavelet analysis was transformed into a powerful mathematical tool, competing side by side with the non local and non temporal Fourier analysis.

Due to its great efficiency in treatment of signals, this analysis had and continues to have an enormous success. Presently, due to the needs imposed by the technological development there is an explosive growth of this new branch of mathematics, in the domain of applications as well as in its theoretical foundations. Currently there is a whole universe of scientific literature that deals with the very different aspects of this wavelet analysis. I must also say that this field of mathematics is developing at such a speed, that the very precise definition of wavelet, that in the beginning was believed to be relatively established, now constitutes a subject about which there are no certainties. These facts caused certain authors to affirm that the precise mathematical definition of wavelet constitutes a question of scholastic nature without any useful meaning.

Here between you and me and to fix ideas, I will consider as basic and fundamental property of the wavelets their localization and finitude characteristics, as opposed to the harmonic waves of Fourier, that are, as we saw, infinite in both space and time. This option results naturally from my main purpose that is mainly centred on the potentialities that this analysis manifests to support a simultaneously causal and local description for the behaviour of quantum beings.

In this new way of understanding the world, the primacy then passes from the infinite harmonic waves to the finite waves. As an example, so that you can have an idea of the situation, between the various wavelets that are known, here is a representation of one of them. Argus drew the following figure:

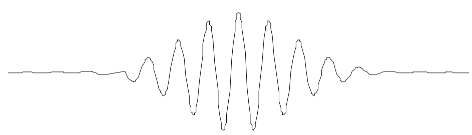


Fig. J5. 1- Morlet’s or Gaussian wavelet

- This drawing – Argus continues – represents a wavelet generally known as Morlet’s wavelet. This wavelet is sometimes also called as Gaussian wavelet.

Now the different signals representing particles, or any other entity, can be described by one or, eventually by a combination of these finite waves. So that we can better compare this new local wavelet analysis with Fourier non local and non temporal analysis let us consider the following drawing.

He paused to draw Fig. J5.2 and then he continued:

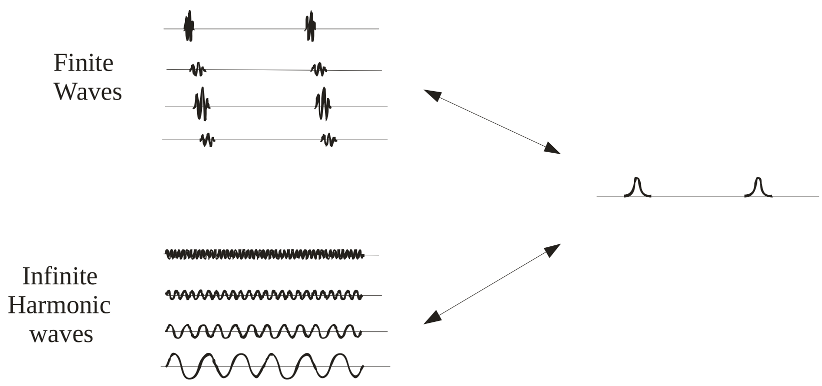


Fig. J5.2 – Composition of the same signal by finite and infinite waves.

- In this figure the same original signal, on the right hand side, is composed, that is, can be reconstructed, by the sum of the finite waves or by the sum of the infinite harmonic waves.

The sum of the first group of finite waves gives rise to the first structure, while the second results from the composition of the second group of wavelets, which is completely independent from the first.

In the case of Fourier infinite harmonic waves, the situation is radically different. Due to their nature, these harmonic waves constitute one sole group whose sum gives rise to an interference resulting in two non null regions that describe the particles. So, any change in the position of one particle implies a change to the waves that also constitute the other particle. As it is the same group of waves that gives rise to the two particles, any change in one implies necessarily a change to the other, even if it remains in the same position.

However, and it is precisely here that the question lies, if the particles are described by groups of different finite waves, as indicated in the drawing, the fact that the particle on the left hand side comes closer or further away does not affect the other in any way. It only becomes necessary to change the group of wavelets that form the first particle, that is, as we saw, totally independent from the second one.

As you can see, in this and other cases, with the analysis of finite waves, the systems can maintain their identity and also own individuality.

When they are composed of infinite harmonic waves, since it is always the same group of waves, the two particles really constitute the same one and indissoluble entity. In this case, as we saw in the last discussion, individuality and separability are nothing more than illusions of our senses

- Ho Argus, I am finding this exposition about these wavelets very interesting but to tell you the truth I haven’t understood very well that question you mentioned regarding the enormous technological advantages that derive from them – I dared to say.

- I think you are right in being puzzled. It is my fault, Liberius – answered Argus. – I was not sufficiently explicit. I think the best process to make the subject clearer is to present a simple example.

As Fabrus and Amadeus love boats, I will draw here two boats sailing in the wind in Tagus estuary. Let us now suppose that Amadeus, who has a video camera, is going to film both boats. In this drawing, (Fig. J5.3) two snaps of a sequence filmed by Amadeus are presented.

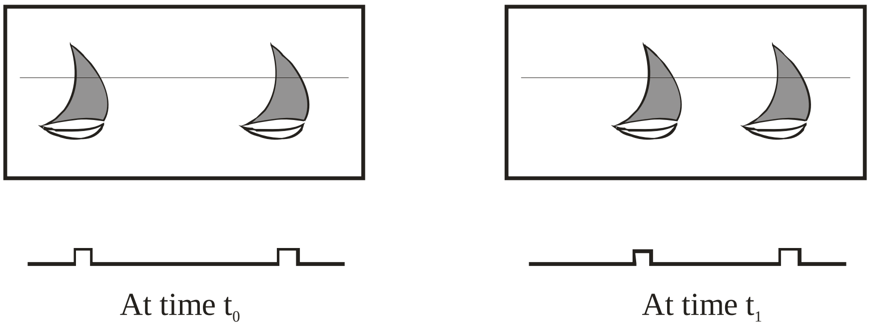


Fig. J5.3. – Two video clips.

As you can see, the only difference between the two clips is the fact that the ships are further away in the first case in relation to the second. The person who is filming is travelling by car on land at the same speed as the boat on the right. The boat on the left is going faster than the one on the right and is gaining ground. The problem that arises is to record these two clips, using firstly the non local analysis, or as it is sometimes called, global and after that the local analysis for finite waves. This recording can be done with any device built for that purpose, a CD, for example.

For that we will record, line by line, the first image being the final reconstruction the result of all those lines. With a view to simplify the problem, let us consider only the line indicated in the drawing, following an analogous process in all the other lines.

As you can see, the line recording the intensity of the image is indicated below the video clip. This record corresponds to an extensive region of null intensity with just two non null regions. These areas represent the respective boat sail sections.

To represent this function, that describes the intensity of the photograph according to the line considered, in terms of Fourier analysis, we will proceed as we did before. So, we will look for the adequate harmonic waves in such a way that their overlapping results null in all the points in space except in those two regions of non null intensity.

In the second drawing the boat on the left went right, while the one on the right remains in the same position to the person who is filming. In the line that we are studying, this situation corresponds to the fact that the non null region on the left is going closer to the non null region on the right. Just like in the case of the line of the first snap let us, in the same way, look for the infinite harmonic waves whose sum has the distribution of intensity as a result.

As this analysis is global, the two boats, although they seem separate, really constitute the one and same entity, as both are the result of the sum of the same infinite harmonic waves. In these conditions, the change of the position of the first boat naturally implies a change in the amplitude, and phase of all the waves so that a constructive interference in the new position results from its overlapping.

Now I want to bring to your attention a very well known fact. In a sequence of video images, due to their speed, various video images are recorded per second, and their number depends on the intended quality. Now, what we can see is that from snap to snap there are not many changes. However, due to the fact that Fourier analysis is global, any change, as small as it may be, in an image forces the whole snap to be analysed.

It is here, Liberius, that the great practical advantage of a local analysis of finite waves lies. If only one region of the image is changed, only the wavelets relative to that location are changed. Therefore, only the information relative to the wavelets that describe that area needs to be treated. For all the other image areas nothing else needs to be done, since that information had previously already been processed.

This process permits, in most cases, to condense information regarding several hours of video recording into only one fraction of them. Basically, it is a great process of deleting unnecessary and redundant information. The economical gain of this process, as you can calculate, is enormous. Can you see the situation? Instead of, for example, 100 CDs being necessary to record video information regarding a family holiday abroad, that same information can be recorded, without any loss, on one simple CD. Do you see the advantage? – he asked turning to me.

- I now understand perfectly the enormous technological advantage of local analysis by finite waves – I admitted.

At this moment Hilarius appeared. He wasn't a very agreeable person due to the fact he was: arrogant, careerist, not as intelligent as he thinks himself to be, and above all, an eager reader of textbooks that he never completely digests. After excusing himself to sit at our table, which he did in his vain manner, he ordered a coffee.

After this pause, Argus started his speech again:

- As I was saying before this interruption, the discovery of local wavelet analysis, not only had great consequences within the technology field, but will also have consequences of a far greater reach in the conceptualization of Nature. The way to proceed towards the rupture with Fourier omnipresent ontology was opened with this discovery. The conceptual tool that allows us to go beyond non local and non temporal analysis was thus created.

At this moment, Hilarius, with his usual arrogance and tactlessness, exclaimed:

- I don't see anything wrong with Fourier analysis! After all, up until now it has always been used with great success, in quantum mechanics and in other applications within the field of classic physics. Moreover, I am certain that its validity was and will always be unquestionable. For that reason, I don't see any need to abandon Fourier analysis.

Amadeus, who is an intelligent, gentile and extremely honest person, not being able to stand this senseless and totally ignorant comment, said:

- Hilarius! It seems to me that you do not see what is really going on. No one here is saying that Fourier analysis is not good, or that it is not precise. What is being discussed is the nature of this analysis. Does it constitute, like other types of analysis, a simple mathematical instrument, as its creator Joseph Fourier intended? Or does it, on the contrary, really constitute a true ontology? In other words, what is at stake is knowing if the harmonic waves, infinite in space and in time, have a privileged status or not. Do they reflect a deeper harmony, suggesting the existence of a Superior Being?

- Amadeus, those questions you are mentioning do not interest me at all. I don't care one bit for perfectly gratuitous and completely irrelevant philosophical questions. What interests me are concrete problems, in sum, physics. All the rest is a joke, speculations, metaphysical deliriums, without any meaning and which are of no importance to anyone - Hilarius replied, in his usual truculent manner.

- Lucius, who did not like the way he had answered Amadeus, decided to participate in the conversation:

- Hilarius, since you are only interested in concrete issues, are you capable of telling me which is the energy of a quantum particle, let us say a neutron, described by a wave-function localized in a certain area of space? Notice that I am asking you which is the energy of that neutron before you have made any kind of observation.

After giving it a little thought, the concerned replied:

- The answer is very simple. All I need to do is Fourier analysis of the wave-function and then I will know the neutron's frequencies, and consequently, its possible energies. Naturally, I will not be able to find its precise energy. Nonetheless, I can tell you the neutron's future energies, and, moreover, the probabilities associated to each of these values.

- Tell me if I have understood your answer correctly, Hilarius — Lucius intervened. — Before the measurement, you do not know the neutron's energy yet. However, you know its possible energies, which are E_1, E_2, E_3... E_n, and you also know the probabilities associated to each of these values. Let us simplify the problem and assume Fourier's decomposition resulted in, for example, only two values to the neutron's possible energies, E_1, E_2; moreover, you also found that the respective probabilities have equal values of one half, $p_1 = p_2 = 1/2$. Thus, in this concrete situation, we would say that, before the measurement, before the observation, the possible energy values, or the neutron's possible energy states, would be either the first, E_1, or the second, E_2, with equal probabilities. Since you did not perform a measurement you do not know, precisely, the concrete value. But you know one thing before the observation: the neutron has one energy value, or the other. Am I translating our thought correctly, Hilarius?

- That is it; that is precisely what I have said!

- Then, we are facing a huge and serious problem – Lucius said. - If, like you have said, before the measurement the neutron is in either one or the other energy state, how can its interferometric properties be explained? How would you explain, then, the two slits' experiment made with one simple neutron?

Notice that, if in the two slits' experiment with only one particle we say the neutron has passed by one slit or the other, an affirmation completely equivalent to the previous one, where we have stated that the neutron's measurement has energy values of E_1 or E_2, we will not be capable of explaining the occurrence of interferences. In order to explain the observed interferences, as Fabrus so perfectly illustrated, we must admit that before the measurement the neutron passed potential and simultaneously through both holes.

Thus, the equivalent answer to the question I made has to be as follows:

Before the measurement, the neutron had simultaneous energy values of E_1 and E_2.

In sum, if your answer had been correct, Hilarius, we would not have interferences!

I shall say even more, if the neutron had one energy value or the other, before the measurement, quantum mechanics would not even exist. Multiple probabilities would not collapse into a single one, once the measurement had been performed. I figure that you know this is one of the more basic postulates in orthodox quantum mechanics. It means your answer implies to completely ignore the extensive wave nature of quantum systems.

Like I say, Hilarius, in these issues of quantum mechanics we must always be attentive, and, for that reason, we must not jump to conclusions. Above all, we must be coherent. We cannot say one thing, and then another completely opposite, for our convenience, without giving any justification. As old people say, you cannot wish for sun to dry your cereal and rain to grow your vegetables at the same time!

In this case, whether we like it or not, to be in agreement with quantum mechanics, we must say that before the measurement, before the multiple states collapsing, the neutron has potentially two energies. In a general case, before the measurement the neutron has a whole multiplicity of energies, as many as the harmonic waves one could derive from Fourier's decomposition. The sum of these harmonic waves, infinite both in space and in time, each one carrying its own frequency and therefore a perfectly defined energy, evidently results in the initial wave function which contains the information we have on the neutron.

In this case, I ask you once more, Hilarius, what is in fact the neutron's energy before measurement?

Now freed from his usual arrogance, and a bit ashamed, Hilarius did not answer this question. After a brief silence, Lucius continued:

- Like I said, before the measurement, and to ensure the corpuscle-wave duality, a fundamental characteristic of quantum mechanics, we must accept that the neutron has every potential energy possible. However, since after the measurement we only find one single neutron, we have, as we can see, problems regarding the status of the neutron’s existence before the measurement.

We are necessarily led here, to this strange situation, if we follow the principles of orthodox quantum mechanics correctly. Behind this conceptual construction, like Fabrus has clearly shown us, we have the primacy of harmonic waves, the only ones that can have a well defined frequency. In fact, this is precisely what characterizes Fourier ontology. In this ontology only infinite harmonic waves have a frequency, and therefore, a perfectly defined energy. As a natural corollary to this basic statement we must conclude that all the remaining finite waves, being necessarily formed by the sum of many harmonic waves, have potentially so many energy values as the waves constituting them. This is where one clearly sees that the conceptual structure of orthodox quantum mechanics is based upon Fourier ontology.

As long as we are it, and to conclude, I would like to point out that the implications which derive from accepting Fourier ontology they are only strange if we believe in causality and in the existence of an objective reality independent from the observer. If we had an idealistic attitude similar to Amadeus’, we would not have a problem at all, quite the contrary; we would have every reason to be pleased.

- Lucius is absolutely right, Hilarius — added Fabrus, who observed the discussion with a smile. - While scrimping in the extensive or wave-like aspects of quantum systems, that is to say, while breaking the indivisible entity of the wave-particle dualism, a fundamental characteristic of quantum mechanics, you made an unfortunately common error, repeated even within the scientific community. Many university teachers teaching quantum mechanics, make basic errors such as yours, and therefore you should know better. Being no more than mere readers of quantum mechanics textbooks, whose content is usually misunderstood, they use in their classes either the classical causal reasoning, or the indeterminist quantum reasoning. All of this in perfect confusion and in a miscellaneous way, completely ignoring the basic and indestructible unity: the wave-corpuscle duality. I feel sorry for the students who follow such masters! From these classes, at best, they will obtain some mathematical techniques, more or less complex, used to solve some problems, and little more. Of quantum mechanics, in fact, they will have learned little or nothing.

Hilarius thought a lot of Fabrus, especially due to his great prestige. After this intervention he left, claiming to have some urgent matters to address.

After this interregnum, due to Hilarius’ unfortunate intervention, Argus continues his speech:

- First of all, I would like to thank Lucius for his intervention, clear and incisive, proof that he perfectly understood the conceptual basis upon which the orthodox quantum mechanics interpretation is based.

However, before proceeding, I would like to further clarify the problem Hilarius rose, regarding the fact that, according to him (and possibly many others), in classical physics there are no problems deriving from the use of Fourier analysis.

In fact, such statement is not true.

As I have had the opportunity to mention, the application of Fourier analysis in classical physics leads, sometimes, to aberrant solutions. These solutions, if taken into consideration, would lead to strange situations, completely deprived of physical meaning. However, since this analysis is considered by those using it, even if implicitly, a simple mathematical tool, these abnormal solutions are not considered as physically valid, and therefore are not taken into account.

This simplistic attitude, and I shall even say opportunist, - which consists of, on one hand accepting or claiming to accept Fourier ontology, and on the other hand implicitly claiming, by convenience, that it is only a simple mathematical tool -, is no longer possible in quantum physics.

Like Lucius and Fabrus clearly substantiated, this is due to the wave-corpuscle duality.

However, going back to what I was saying, the discovery of wavelets makes it possible for us to go beyond the omnipresence of Fourier ontology. This ontology, as I have previously mentioned, and Lucius made evident, is supported by the basic assumption that only infinite harmonic plane waves have a well defined frequency. All remaining waves are necessarily composed, and in a last analysis, by the sum of these harmonic waves.

It takes courage to break things like this! It implies claiming that in certain conditions it is possible to have impulses, that is to say, finite waves with a well defined frequency.

To place the problem in proper perspective, consider this sketch I am drawing. The drawing intends to represent a brick with the shape of a wave.

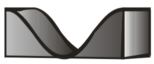


Fig. J5.4 – Basic brick of ¼ m in length.

The outline of this brick in the shape of a wave, or, in mathematical language, in the shape of a cosine, has 1/4 m, that is, 25 cm in length. Let us now assume we have built walls with similar bricks. The first of these walls has 1 meter in length and is formed by four bricks:

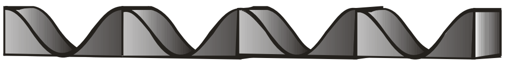


Fig. J5.5 — One meter wall formed by four bricks.

The second wall has 2 meters and is formed by 8 bricks:

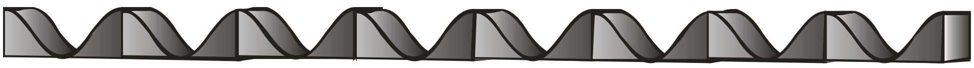


Fig. J5.6 — 2 meter wall formed by 8 bricks.

We can continue building walls by doubling the length permanently. Thus, we will end up with 4m, 8m, 16m, 32m walls, and so on. Naturally, since these are real physical walls, the possible length is always finite.

I believe you all agree with my statement, that all real walls may be really big, or really huge; however, naturally, no matter how big they are, they must necessarily be finite.

I now would like to call your attention to the concept of frequency. This term means the number of times a certain element is repeated in a given measurement pattern.

Let us imagine we have a hedge with regularly spaced shrubs. The frequency of the shrubs shall be, naturally, their number by length unit, for example, two shrubs by meter. In this case we are speaking of a spatial frequency, since the elements are distributed in space. When we speak of elements distributed in time, for example the rhythmic sound of a drum, we have a time frequency. Let us admit that the percussions originating sounds are regularly spaced in time. Let us assume they were produced at a rhythm of five per second. We would have, in this case, a time frequency of five beats per second. With these considerations in mind, I would like to ask a question: Tell, me Amadeus, which do you think is the spatial frequency of the first wall, the one with one meter in length?

- After all you have said, the answer to your question would seem extremely easy. If the wall has one meter in length and is made of four bricks, then its spatial frequency is four bricks by meter.

- And now what would you say if the wall has 2m or 4m, does the frequency changes?

- Since the number of bricks per length unit is maintained constant in all walls, its frequency remains constant whatever its length may be and it will always be of four bricks per meter – Amadeus replied.

- Your answer, Amadeus, is dictated by the good sense; I should say even more, it results from the use of a sane causal rationality deprived of the implicit assumptions of an idealistic nature.

However, in terms of Fourier ontology, where, as we have seen, following the circularity paradigm of Plato faithfully, primacy is given to infinite harmonic plane waves, so that is not the correct answer!

- I'll be blessed - Lucius replied -, you are then implying that the frequency of the walls may depend on their length!

- Although it may seem bizarre, that is claimed in Fourier ontology – answered Argus. – We have seen before – he proceeded – that when we have an impulse, a finite sign, which in the specific case of the walls' outline they are pieces of the same cosine function with different sizes, what we can do in terms of Fourier analysis is to find a combination of plane harmonic waves with frequencies, phases and amplitudes adequate in a way that their sum equals the referred function piece. Since in this ontology only one of these infinite harmonic waves matches a well defined frequency, we can naturally conclude that the wall we are seeing, in this perspective, does not have one single frequency but a multiplicity of frequencies.

It can be verified, as I hope to demonstrate ahead, that the smaller the function is, in this case a piece of a cosine function that constitutes the wall's outline, the greater the multiplicity of harmonic waves necessary to make up its reconstitution.

On the contrary, when the wall's length increases, the multiplicity of waves necessary for the reconstitution diminishes.

In a limit situation, if the wall was infinite, which as we have seen is a physical impossibility, the wave which describes the wall's outline would be a single harmonic wave and then, only then it would have a defined perfect frequency.

In summary, this ontology claims that only an infinite wall, physically inexistent, has a well defined frequency. All the remaining finite physical walls do not have a well defined frequency, but a multiplicity of them. The multiplicity of these frequencies is greater when the length of the wall is smaller.

As I have said initially, it is necessary to break this omnipresence of Fourier ontology. If this ontology is taken to the last consequences, it drags us, as we have seen, to severely disastrous consequences.

Numerous facts show us the evidence that in certain conditions, like for example in the case of the walls, there may be finite waves, finite impulses, with a well defined frequency. As a matter a fact, this conclusion does not bring novelty, since we know that musical instruments, like organs and pianos, if well calibrated, can produce a sound with a very well defined time frequency, even if these signs, naturally, have a beginning, and necessarily an end.

- By the way, Argus - Lucius said – I think you have nothing against using Fourier analysis as a simple mathematical instrument to solve certain problems.

-Of course not. The mathematical instrument, which is Fourier analysis, is quite useful when it comes to solving a number of concrete problems. However, we must be careful and pay attention to its non local implications – Argus replied. – Once liberated from this heavy ontological burden, where there is no possibility of separability, and therefore individuality, we may undertake the construction of a new causal and local quantum physics, with the help of wavelets. This new physics must be a more general physics, more comprehensive than the previous one, which is based mainly on linear equations. It must be a physics of a superior level, a physics of the nonlinear; in other words, a second level physics.

- By the way - Amadeus commented – I have often heard of linear and nonlinear, even in previous dialogues. But I must say I never quite understood what it is about. Is it possible to clarify this issue a little, which after all seems so important?

- I will be delighted to clarify that for you, Amadeus – Argus answered. – Technically, we can say that linear systems, as the name implies, are the ones described by differential linear equations. Thus, if two or more functions are the solution for a given linear equation, their sum will also be the solution for that very equation. When it comes to nonlinear systems, generally, this property is no longer valid. I imagine that with this definition, which is the classical one, you are exactly where you were before.

- You are right, Argus. With the technical explanation you have given me, I now know precisely the same I did before – agreed Amadeus.

- That is precisely where the problem is. Most people confuse physics with mathematics. Physics is one thing; mathematics is another. Beethoven's seventh symphony is one thing; musical symbols and the rules of musical composition are another.

In order to truly understand what a linear system is, we must go way beyond simple formal mathematical rules. In fact, this linear process is practically as ancient as man himself since, no doubt for being so simple and efficient, it was already used by the first human beings in problem solving. Whenever we have a very complex problem on our hands, the most common and most used process to solve it is to divide it into parts, after which, one tries to study each of the parts separately. If these parts are still difficult to solve, we continue dividing until each of the sub-parts can be handled. In the end, we join all partial solutions and we have the answer to a complex problem.

Amadeus, imagine that you are in charge of making the project of a house. As you well know, this is a very complex problem. Nonetheless, the procedure to solve it is quite simple. The general process to undergo would be, such as we have seen before, decomposing the problem in two parts. The artistic or architectural part; and the technical part, which involves structure, piping, electricity and gas. However, since each of these divisions are still significantly huge, we must go on sub-dividing each one of them into smaller parcels, which will be handled in turns. The final project for the house is no more than the sum of all these parts and sub-parts.

In summary, when we have a linear system, the whole equals the sum of its parts. However, when it comes to a nonlinear, that is not generally true. In fact, only from an initial approach, and in very simple problems, we can say that the whole equals the sum of its parts. There is always a mutual large or small interaction between the different elements, which makes the whole different from the simple sum of its parts.

Even in the case of the house, the whole is generally different from the sum of its parts. If the architect does not constantly accompany the works, correcting something here and adding something there, modifying as he may see fit, integrating and harmonizing all the pieces into a unique whole, the house will certainly be, at best, an adulterated copy of another house, or even a mere cluster of bricks and other materials.

- I think I have now well understood the meaning of linear and, consequently, of the nonlinear – Amadeus exclaimed. – If I caught your reasoning correctly, physics handled problems as if the whole equalled the sum of its parts. Like you said, this is an expedite method, and moreover, gifted with a huge degree of efficiency. However, it is only a first approach, since generally problems are much more complex. As you have said, there is always interdependence, reciprocal interaction between the several elements. I now perfectly understand it when you say that in order to make advances in the knowledge of Nature, one needs to walk towards nonlinear physics.

- I am very pleased to see you perfectly understood the situation. But resuming my speech - Argus continued – this new second level and more general physics, must contain the previous first level linear physics, as a particular case. This happens for an obvious reason, since linear physics, within its sphere of applications, is a good method to describe certain aspects of reality.

On the other hand, one must take into consideration that Nature is *one*[4]. For that reason, there must not be a rupture, a conceptual abyss, between classical physics and the new quantum physics. On the contrary, it must be possible to pass from one to the other in a perfectly natural manner.

We verify that in quantum physics the extensive and the localized, the wave and the corpuscle, in summary the wave-corpuscle duality constitutes something basic. However, we also know that in classical physics there are two fundamental equations,

[4] TN: From the Latin *Uno*, roughly speaking the philosophical concept of *Uno* means the unity of the whole, indivisible; vide Plato, Neoplatonism and Hegel.

one describing corpuscular or punctual systems, and the other describing extensive systems.

The first is the fundamental equation of mechanics. It is Hamilton-Jacobi's designated equation, which is no more than a conservation equation. In reality, this equation says that a system's total energy equals the sum of kinetic energy and potential energy.

The second is a basic equation of extensive systems, of hydrodynamics, which is called the continuity equation, and which, just like the previous one, is also a conservation equation.

Now, the basic idea is to fuse both equations into a single equation, containing, at the same time, local or corpuscular nature and extensive or wave nature.

The fusion of these two classical physics fundamental equations generates a nonlinear equation integrating the wave-corpuscle dualism in a unique whole.

Armed with such conceptual tools, we may now elaborate a global synthesis, coherent and objective, of classical physics and quantum physics. In such a synthesis, as we have made reference, we assume that reality is *one*[5] and exists independently from the observer. Naturally, there is a notion that the observer interacts with that same Nature, from which he is part of, being eventually capable of modifying it, to a major or lesser degree. Thus, classical physics and quantum physics simply correspond to different levels of description, different scales of observation of one same reality.

A simple but illustrative example of this situation is the entity we call water. In the light of a macroscopic description, this entity can and should be considered a continuous extensive system. However, in the light of a microscopic system it is more useful to describe that very entity as a discontinuous system made of molecules. In fact, this is the same very entity for both cases, water! Nonetheless, according to the description's level, it would be more convenient to consider this entity continuous, in some cases, or discrete, in others.

At the level of classical physics description, local systems like corpuscles, and extensive systems like waves, are viewed as independent realities. In such conditions, they are naturally described mathematically, through different equations.

At a quantum scale, this local and extensive dichotomy has no sense whatsoever. Localization and extensiveness are integrated in a unique whole. This unique entity, wave-corpuscle, is now described through a single equation. Like I said, this final equation, resulting from the composition of the Hamilton-Jacobi equation and the continuity equation, is no longer a linear equation, but a nonlinear equation.

In these terms, we may say that classical physics is a particular case of quantum description when the unity of the wave-corpuscle is broken, and these two different properties of the physical systems may be handled as independent. Thus, the nonlinear fundamental equation, at a quantum scale, originates two equations, one for corpuscles, and another for waves, whose solutions are then handled as independent entities.

Symmetrically, we can say that quantum physics is no more than an extension or a generalization of classical physics, where the extensive and the local aspects are considered a whole. This way, by fusing both of the classical physics fundamental equations it is possible to obtain the nonlinear master equation that describes

[5] Vide previous reference.

phenomena at a quantum scale.

This global synthesis between the two levels, or scales, of description of the objective Reality is schematized in the next drawing.

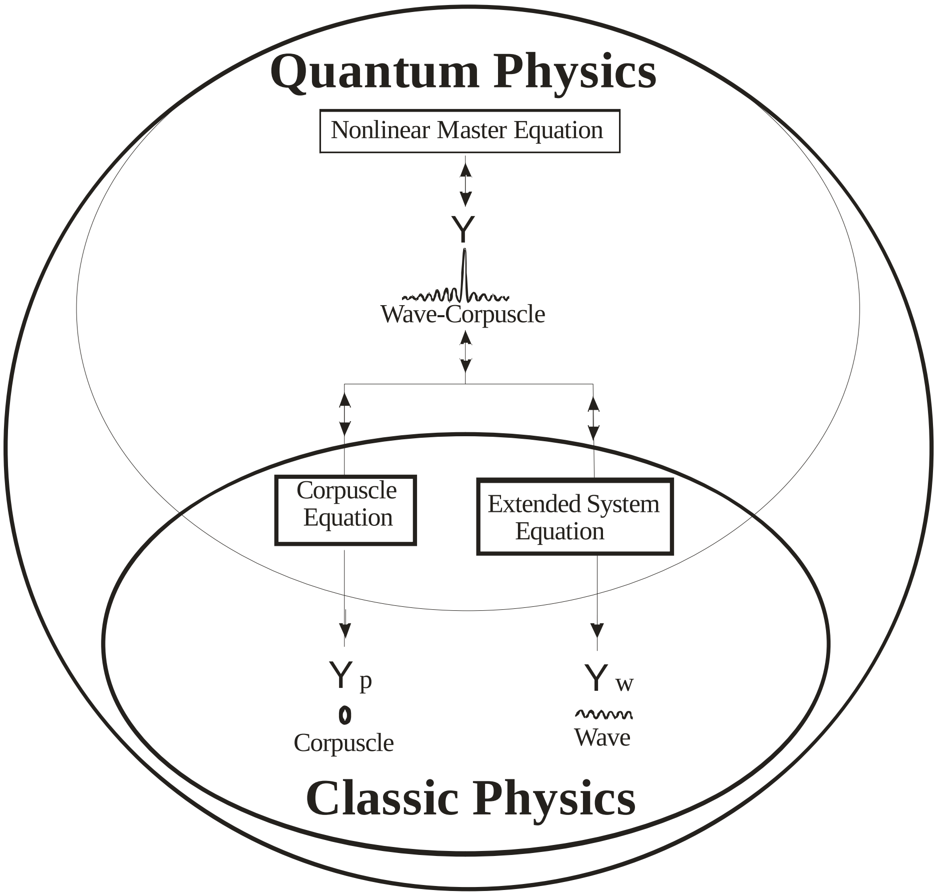


Fig. J5.7 – Synthesis of quantum physics and classical physics.

As we can see in this representation, from the fundamental nonlinear equation we come to the basic equations of classical physics. Hamilton-Jacobi's equation for localized systems; and the continuity equation for extensive systems. Thus, we can verify that from the causal local and nonlinear quantum physics we can reach classical physics. On the other hand, as we can also see in the drawing, the reverse path is also perfectly possible. This means that by fusing both classical equations we come to the fundamental nonlinear equation of the new quantum physics.

Since it was now very late, we have all agreed to interrupt our discussion, being careful to schedule the date and time of the following journey.

SIXTH JOURNEY

Late that pleasant afternoon, I was once again heading to the Eternal Return bookstore. Since I had some free time left, I was walking slowly in order to enjoy the magnificent view over Lisbon that one can perceive from Miradouro[6] de São Pedro de Alcântara. While I was walking, I meditated on the subject of our discussion. I must say that, this time, I was happier than before. The explanations Argus provided allowed us to foresee the possibility of creating a causal physics. In such physics, the anti-realism of the Copenhagen School would be set aside, again giving rise to causal physics. Thus, the existence of an objective reality independent from the observer would be re-established. We would no longer live in a world of shadows and illusion.

This time, when I arrived at the Eternal Return Bookstore-Café all the elements of our group were already there. As usual, Argus and Fabrus drank tea, while Lucius and Amadeus drank beer. Since I was thirsty, I also ordered myself a beer.

After the usual greetings and the introductory chat, Argus regained the speech where he had left it in the previous journey.

- To be exact, and to be faithful to the historical truth, I must say that the dawn of this new causal physics took place about a century ago, with Louis de Broglie. As we have seen, whatever quantum theory one builds, it ultimately has to be able to explain the basic identity issue, a characteristic of the quantum level; that is to say, it has to be able to interpret the wave-corpuscle dualism. We also know that Niels Bohr succeeded, in 1927, the remarkable achievement of interpreting it in his own way. On the other hand, we also know this integration was obtained at a very high cost. The price of this integration, as we have seen, was the acceptance of the impossibility to decide on the existence of an objective reality. For him, and I have said this before, quantum formalism expresses in a mathematically lucid manner the existence of an irreducible irrational residue. For that reason, according to him, it will never be possible to accept the existence of an objective reality; he thus assumes an anti-realistic position.

Louis de Broglie, on the contrary, in order to solve the enigma of the wave-particle dualism, follows a realistic and casual approach. He will then say that what we call quantum particle is, in rigour, a very complex entity which does more than simply occupy space; this approach is too simplistic to describe all the wealth and complexity of that quantum entity we call particle. In fact, the quantum particle is composed of a very high localized structure, a kind of nucleus, now named acron, and a guiding wave. This acron is responsible for the corpuscular characteristics, and carrying practically all of the particle's energy, it is located in the guiding wave, sometimes also referred to as theta wave. An approximate representation of that quantum particle is as follows – and he draws the following sketch:

[6] TN: A place with a panoramic view of the city.

Fig. J6.1 – Schematic representation of a quantum particle.

In this sketch we represent the acron in the centre of the wave. However, it can occupy any position within the guiding wave, where its intensity is not null. Since the theta wave's energy is much inferior than the energy of the acron, one can only detect this guiding wave through indirect methods. These indirect processes that reveal the existence of theta waves will be discussed later on. The detection of such wave, as you should understand, offers certain experimental difficulties, since common detectors do not have the capacity to react to its very low energy. When a detector produces a click, announcing the arrival of a particle, what the detector really "sees" is the energy of the acron. That is, what, in reality, is detected is the presence of the acron.

- Argus, I do not quite understand what you call quantum particle. Could you clarify on this subject? – Amadeus asks.

- Well - Argus answered -, I can try to present a macroscopic model of a quantum particle. Nonetheless, you must bear in mind that any macroscopic model, however complex and elaborate it may be, will always be, at best, a rough approximation of that complex reality we call quantum particle.

To settle our ideas, let us consider a huge tropical storm, a hurricane, which is quite common in the Mexican Gulf. As we know, its nucleus or the region carrying a major concentration of energy, occupies a relatively small volume around the central area. We also know that, precisely in the central area, there is a small region where there is practically no wind. When I speak of the hurricane's nucleus I mean the extremely localized area that, even including a region with no wind, still carries a great concentration of energy, in its whole.

Let us now imagine an observer located in a spaceship overflying the region at high altitude. To simplify the issue even further, let us admit that the observer does not feel the effects of the hurricane due to the high altitude of his position. On the other hand, let us further admit that, due to the special means he possesses, this observer cannot directly see this atmospheric phenomenon, since his task consists only in observing what happens in a given city. The hurricane, in its course, is heading to the observed city. Two situations may occur:

The hurricane's central area does not reach the city, or its central area reaches the city. In the first scenario only the extensive area, in this simplified model carrying a relatively small energy, reaches the city. In this case, the houses which form the city will not be significantly damaged. At most, a broken window or two, some lifted shingles here and there, obviously depending on the quality of the buildings' construction. In this situation, the observer has no possibility of deducing, from these minor effects, the hurricane's existence. Yet, if the hurricane's nucleus hits the city it will create a trail of devastation behind it. In such conditions, our observer, when perceiving this havoc, may then conclude that the hurricane has hit the city.

Tell me, Amadeus, have you now understood a little bit better what a quantum particle is?

- I believe so - answered Amadeus. – In that rough image you referred to, the hurricane's nucleus represents the acron, while the extensive region represents the guiding wave. I now begin to understand why you have said that what is usually observed is only the acron. Since the guiding wave carries very little energy, its effects can only be observed in very specific conditions. Thus, from what I have inferred, we conclude that in usual conditions this wave is undetectable.

- Since that issue is clarified, I shall now proceed - said Argus, resuming his speech. – There is still a very important issue here that needs clarification. It is the relation between this guiding wave, or theta wave, and its acron. In my opinion, to have enlightened us on this situation was one of Louis de Broglie's more fertile contributions to physics. This physicist assumes that the acron, even possessing a very high relative energy, will nonetheless be guided, oriented, by the associated wave. It is this wave of very small energy that, in a last analysis, defines the course the acron will follow.

De Broglie called this enunciate a guiding principle. He claims, explicitly, that the probability of locating the acron is proportional to the intensity of the guiding wave. Thus, for example, in an area of space where there is no theta wave, there will certainly be no acron.

With the introduction of Louis de Broglie's guiding principle, the path to nonlinear physics was opened or, in other words, a second level physics where energy exchanges no longer play the leading part.

At this point, Lucius placed a question:

- Tell me, Argus, if I have clearly understood your position. You were referring that in the new causal physics the information exchanges are what matter the most, in detriment of energy exchanges as people believed until now. Do you mean that the concept of energy and its conservation has lost its meaning?

- I would never claim such a thing - Argus exclaimed. - The concept of energy and its conservation, which arose in the mid 19^{th} century, is surely one of the most fertile concepts created so far. Its validity and generality are not in question. What I stated was that, in certain situations, where energy conservation evidently exists, the best way to describe what happens is to resort to something similar to the information concept.

In order to clarify this, let's consider the following situation that intends to illustrate what happens in a more simplified way: let's consider a high speed train moving at for instance 380 km/h. This train's energy is certainly huge, especially when compared to the energy that each one of us is able to expend! I believe there are no doubts on this issue. This train follows its course until it finds a railway knot. From this knot three tracks diverge: one straight on, one to the right and one to the left. The railroad switch operator, with a single movement can make the train go straight on, to the right or to the left. In reality, the operator, expending very little energy, conducts and determines the course of the train, even if this train's energy is immense. Naturally there is energy conservation in the process. However, what is at stake here, given these very special circumstances, is the insurmountable fact that the use of this relatively small energy, in this case the effort to move a lever, holds the possibility to unleash remarkable effects. In reality, what happens is that in certain situations a minimum action has the ability to unleash such a reaction that there is no relation, energetically speaking, between cause and effect.

Do you think that, with this extremely simplified example, I have been sufficiently explicit?

- I believe I understood your point of view quite well – Lucius replied. – And I tell you more, it seems to me that this new physics opens unsuspected frontiers in the field of development and exploitation of new energy forms. What do you think of this, Argus?

- Well, truth be told, Louis de Broglie referred to the gigantic energy that exists in what he called the subquantum medium. What we still do not have are “windmills” capable of capturing those immense flows of energy.

Argus paused for a while and the proceeded:

- In order to immediately clarify the fertility of this quantum particle’s model, I shall explain the two slits’ experiment in purely causal terms.

Let us then see what happens with this new approach – and he began to draw:

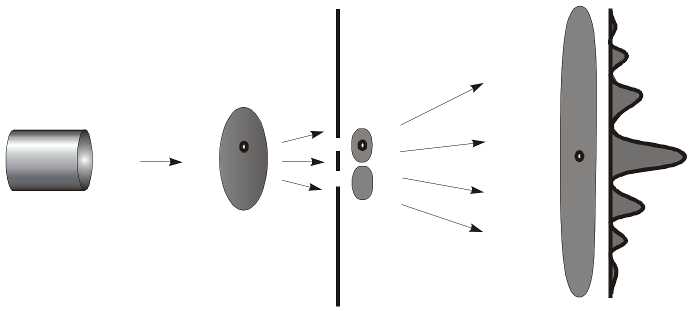


Fig. J6.2 – Two slits’ experiment in the causal model.

In this drawing, like in the previously drawings representing this situation, we can see a source issuing quantum particles, one by one. This quantum particle is formed by the guiding wave, extensive but finite, carrying within the extremely localized corpuscle, the acron. When arriving at the screen, what happens is that the guiding wave, being extensive, passes through both holes at the same time. The acron, or corpuscle, being very small in size and indivisible, can only cross one hole or the other, incorporated in one guiding wave or the other. In their course, these two waves will expand and overlap, originating a total wave on the target detector. This total wave, which carries the acron, resulting from the sum of the two waves, has an interferential form, as we know. And this total wave will now guide the acron. This guiding action, this nonlinear effect, is processed in a way that, preferably, the corpuscle will move towards the regions where the total wave has greater intensity. Thus, when an acron reaches the detector, it originates something which is strongly localized that results from the interaction between the acron and the detector; and, according to the guiding principle, it is preferably localized in the regions with greater probability, that is to say, in the zones where the total wave's intensity is greater. After some time, another acron inside its wave reaches the target detector, enduring a similar action, and so on. As time goes by, the distribution of such impacts on the target detector progressively emerges, outlining an interferential distribution. In the beginning, this interferential distribution is not completely visible. However, after some time, the distribution of dots in the target detector begins to stabilize, thus becoming a perfectly visible interferential image. As we have seen, the apparent contradiction arose by the wave-corpuscle dualism, a problem the physics faced in the first quarter of the 20th century, deriving from the fact that the quantum particle has to cross 1) one hole *or* the other, 2) one hole *and* the other... has been solved in a perfectly clear manner. This explanation, simple and intuitive, can be summarized as follows:

1) the acron crosses ------------------------ one hole *or* the other;

2) the extensive guiding wave crosses --- one hole *and* the other.

- Argus! I like this explanation better. It is certainly more natural that the strange, not to mention incomprehensible, explanation Bohr provided – Lucius remarked, excited, and continued:

- With an explanation such as this you end up showing that it is possible, after all, to solve, in purely causal terms, the great conflict imposed by the wave-corpuscle dualism. I even dare to say that this great problem may be dealt with, by resorting to a simple, intuitive and extremely elegant explanation. All this, without the need to claim the existence of an irreducible irrational residue that limits our possibility of accessing a causal description of reality. From now on, one can no longer say that this indissoluble quantum entity, which is the wave-corpuscle dualism, implicates rejecting the existence of an objective reality, independent from the observer.

Now, the question that crosses my mind is why this clear and natural explanation was not accepted sooner. Why was that?

Here, Fabrus decided to take the word.

- The main reason was especially due to the huge efficiency of quantum mechanics in the description of quantum phenomena. The power it revealed was so overwhelming that even those who never agreed with Bohr's interpretation of quantum formalism had to bow. Louis de Broglie himself, after the Solvay Congress in 1927, returned to Paris and up until 1952, could not help but to teach the Bohrean interpretation in his quantum mechanics classes at the University of Paris. All that Argus has been saying so far may be beautiful, but he has to prove that the ontological commitment of Louis de Broglie, which he just mentioned, allows for a description of the same phenomena that can be handled by Bohrean quantum mechanics, and also the ones it cannot describe. This is equivalent to showing that Bohrean's interpretation of quantum mechanics is an incomplete theory. What happens is that so far, as far as I know, no one has succeeded in that. I admit that by adopting a realistic philosophical position, Louis de Broglie and our friend Argus are coherent when they start with an ontological commitment like the one he just described. Now, for this to be acceptable, it is necessary that they can build a mathematical description of that new project of theory which proves to be even more efficient than the present quantum formalism: it must have a quantitative concordance within an approximation that can be compared, at the least, to the one evidenced by Bohrean's quantum mechanics; it must predict phenomena unsuspected so far, it must be able to increase, beyond what quantum mechanics has already achieved, our capacity to act in the world, through the construction of new tools, which would be unconceivable without this theory.

In silence, we looked at Argus. He smiled and answered:

- I accept your challenge, Fabrus. If I didn't, I would not be coherent since those are precisely the criteria I have been defending until now. Any theory worthy of such name must fulfil those requirements. I hope that, by the end of these dialogues, your objections have been completely removed. Give some time. But now I will answer Lucius' question.

The answer to your question, Lucius, is not an easy one, as you may figure! Anyway, a simple attempt to reply holds several components:

On one hand, we have the well-known situation, and unanimously accepted: the conclusions of the Solvay Congress in 1927. In this international congress, the Bohrean vision rose above all others, due to what Fabrus has put forth, but also due to the fact that the causal nucleus, which reflected the opposition, did not constitute, in fact, a solid and coherent ensemble. This nucleus, or better, this grouping that opposed to indeterminism, or to Bohrean's interpretation, was formed by Louis de Broglie, Max Planck, Schrödinger, Einstein, among others. In spite of individually opposing to Bohr, they did not, nonetheless, agree among themselves. Each of them had their own theory, or better, a project of a theory, because these were really no more than projects. At best, these were no more than sketches, more or less developed. In spite that, none of them wished to give up on their own ideas in search of common grounds. They were not capable of forming a common front that could oppose Bohr and his supporters.

Thus, it is no surprise that the Copenhagen School, gathered under the baton of the great maestro Niels Bohr, had not faced any resistance worthy of that name. On the other hand, it is important to clarify that, truth be told, and agreeing with Fabrus' recent affirmations, this school was able to present a coherent and consistent theory of the known quantum phenomena. Regarding simple efficiency, until very recently, Bohrean's quantum mechanics has proven unsurpassable. But, as I have mentioned in previous conversations, it is still a human work, with all the frailties that it implies. It describes the intended phenomena with great rigour, but it is not, nor could it ever be THE THEORY.

Bohr's great ingenuity was to think that, finally, we understood why we did not understand the world; it was thinking that the limits for our ability to rationally understand the world were now defined by quantum mechanics. From this point of view, this is an attitude similar to the Newtonians' of the 18th century when they believed Newton had discovered the laws of this world and that, from then on, we would not be able to do more than add some decimals to the precision of our descriptions. Today, we find it easy to see those Newtonians ingenuity. But for some, there is still a certain difficulty in seeing that same ingenuity in Bohr's belief that the limits to our ability to rationally understand the world were now defined, once and for all.

Argus stopped, somewhat meditative, while we looked at him, curiously. He then raised his head and proceeded:

- On the other hand, let us not forget that there is something we already mentioned and which is of vital importance. Many forget this. This basic component, this postulate, was camouflaged in such a way that until very recently it had been practically unnoticed.

It is spread through the several postulates of quantum mechanics, but is never assumed explicitly. It is Fourier ontology, which, as we have seen, holds the foundations of all orthodox interpretation of quantum mechanics. In fact, Niels Bohr's principle of complementarity, a crucial element of the orthodox quantum mechanics, is mathematically translated in Heisenberg's relations of indetermination. But they are mere consequences of this ontology. It was the power and the efficiency of quantum formalism that led physicists to accept a hidden unopposed ontology in which the bricks to build our understanding of the world were harmonic infinite waves. Bohr managed to pass on, as if dogmatic, the idea that only one harmonic plane wave, which by its own nature could not physically exist, can have a well defined frequency!

Thus, any finite physical impulse, not being able to have a well defined frequency, must have a multiplicity of frequencies, as many as the infinite harmonic waves resulting from Fourier's decomposition, necessary to reconstruct it.

Good sense should have told us that this was a mere formal decomposition, a simple mathematical artifice, of course very convenient, but nothing beyond that. This happens for a good reason, since real physical waves are necessarily finite waves, even if eventually very extensive. Naturally, in their classical applications, the users of Fourier analysis do not specifically attribute a real existence to the harmonic waves. Such would not be possible, since not even Niels Bohr himself gave them that status. To him, as we know, such waves are endowed with an existence that is merely potential. However, when accepting that only an infinite harmonic plane wave can have a well defined frequency, the users are simultaneously denying the possibility of an impulse, or a finite wave, having a well determined energy.

This ontology's starting points can be thus summarized:

P1) Only infinite harmonic waves in space and time have a well defined frequency;

P2) The time frequency *w* and the spacial frequency *k* are related through Planck's constant *h* with the empirical formulas of Planck-Einstein *(E = hw)* and Louis de Broglie (p = *hk*); where p = *mv*, the product of the mass by velocity, represents the quantum particle's moment.

In such conditions, this ontology, which associates the two fundamental empirical formulas of quantum physics exclusively with the frequency of infinite harmonic waves, leads us, whether we like it or not, to conclude that if a quantum particle has a well defined energy, then it necessarily occupies all of space and all of time.

However, when using this non local and non temporal analysis, in solving concrete classical problems, it leads to contradictions, these users do not hesitate in setting such aberrant solutions aside, taking them as physically deprived of sense in a perfect logical contradiction regarding the initial principles.

Anyway, and as strange as it may seem, the fact is that this implicit ontology has been adopted by the scientific community, even if sometimes quite contradictorily. Once this ontology is accepted, we will have to admit, for the sake of coherence, that the concepts of space and time can no longer be considered the foundations of our understanding.

Now it is easy to understand why all efforts developed did not flourish for over half a century, by those who did not accept Bohr indeterminism. They were tightened by the conceptual frame of Fourier ontology, and had no chance of building a real quantum causal and local theory. In fact, such a causal theory was, at best, destined to partial success, right from the start. That is what happened to David Bohm's interpretation of quantum formalism. It can predict every result of experiments the orthodox interpretation predicts, but no more. It cannot conceive an experiment in which his interpretation predicts a result different from the usual interpretation. And we all agree that such a demand is indispensable to point out the superiority of his interpretation. Of course, in case the results of the experiment agree with what his theory predicts.

We are now capable of understanding the great handiness and sagacity with which Niels Bohr acted: he made Fourier ontology to be accepted so innocuously that practically no one, within the scientific community, perceived its true non local and non temporal implications. Concomitantly, he built his quantum theory based on such ontology. In these conditions, one cannot be surprised to see that any attempt to build an alternative theory intending to safeguard a causal and local description, but accepting Fourier ontology, explicit or implicitly, would be inevitably doomed to failure.

An example that perfectly illustrates this situation, is the so called EPR paradox.

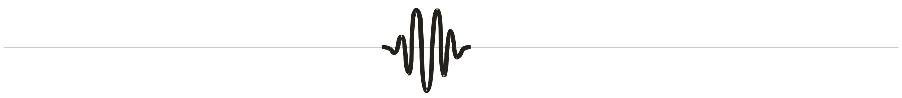
This paradox was proposed by Einstein, Podolski and Rosen in 1935. In it, its authors aimed to find a flaw in orthodox quantum mechanics, without questioning, at the outset, Fourier ontology. In an extremely simplified way, the idea behind this paradox can be translated as follows:

In a given moment, both co-related quantum systems are joined, occupying the same region of space. In order to simplify, let us imagine these are two quantum entities called Joseph and Mary. In the next moment, these quantum systems shall part, each following its own course. Like in the two slits' experiment, we do not know, and can never find out, before performing a measurement, if Joseph or Mary will follow one or the other direction. So, to be coherent with the wave-corpuscle duality, we must admit that Joseph and Mary are going simultaneously in each possible direction. We can also say, in short, that a complex quantum entity designated as (Joseph-Mary) follows each one of the paths.

If an observer placed, for example, in the left path, verifies that Mary is coming, he can immediately conclude that Joseph is on the other path at the right.

This finding, this measurement, would be performed without any physical action being exerted on the quantum entity Joseph-Mary following the path at the right. Thus, in this perspective, we would have achieved a remarkable deed. We would have determined that Joseph was following the path at the right, having so determined without the need to resort to any physical action over the referred quantum entity. This result would be, according to its authors, in contradiction with orthodox quantum mechanics.

Now, that is precisely where such an analysis is wrong. Let us see how the situation should be described in terms of orthodox quantum mechanics, that is to say, within the conceptual frame of Fourier ontology. Initially, we have a quantum system (Joseph-Mary) occupying a small region of space. As we have previously seen, this system derives from the overlapping of many of Fourier's harmonic plane waves, which upon overlapping, will interfere negatively in all of space, except in that area, as shown by the sketch – and he draws:



(Joseph-Mary)

Fig. J6.3 - Initially, the quantum system (Joseph-Mary) occupies a region in space.

Later, this system divides originating into two, each following its own path, as we can see from the in the picture. Since we do not know, and can never find out without modifying the system, if Mary or Joseph go left or right, we have to admit, for the sake of coherence with the wave-corpuscle duality, that (Joseph-Mary) are simultaneously going to the right and to the left, as we can see in this Fig. J6.4:

(Joseph-Mary)-L (Joseph-Mary)-R

Fig. J6.4 — After the separation, we will have the quantum system (Joseph-Mary) simultaneously following both paths.

The fact that the quantum system (Joseph-Mary)-L, from the left, is more or less spatially separated from the one going to the right, does not mean that they are independent entities. As we know, in this ontology, both these quantum systems are made of the same harmonic plane waves. The only difference is that now these infinite waves that constitute them are related in a way that constructive interference can only occur in the regions where both quantum systems are localized, (Joseph-Mary)-L, going to the left, and (Joseph-Mary)-R, going to the right. When we perform the measurement of the quantum system (Joseph-Mary)-L, that follows the left path, what we are doing in this context is to interact with waves which constitute that entity. But since the waves which constitute the entity on the left are the same constituting the entity on the right, when practicing an action on the left quantum entity this will also have repercussions on the one on the right, no matter how apart they are. This happens because, under the terms of Fourier ontology, both quantum entities constitute a single global entity. Its separation would be an illusion, resulting only in a mere deception to our senses.

From all of this, we only have two possibilities: either we reject Fourier ontology from the start, and we are free to elaborate a local and causal description; or, in case we explicit or implicitly accept it, we must abide by the rules of the game, thus falling in the Bohrean interpretation, introducing the principle of complementarity, or accepting David Bohm’s indivisible Universe, and therefore, non locality.

- From what you have said, Argus, I inferred that Niels Bohr did not give his opponents a chance! – Lucius exclaimed. – He forced Fourier ontology onto them; even he had never made it explicit. Upon accepting it, there would be no opportunity to escape. Whether they liked it or not, they would have to play the game according to the implicit non localization rules.

I now understand why it was so hard, during almost all of the 20th century, to surpass the boundaries that quantum formalism had erected. By accepting Fourier ontology they where implicitly accepting the non localization. I see here a clear analogy with what happens in certain unpleasant circumstances in which drivers, and I am speaking out of my own experience, get involved. They intend to go somewhere, but due to a distraction, or a confusion with the traffic signs indicating directions, and sometimes simply because these are not well placed in the road, they make a mistake and follow an undesired course. That has happened to me once, when I wanted to go to Cascais. I left Lisbon through the North-South highway, leading to Cascais, and I don't know how I did it, but I found myself on the way to the Bridge 25 de Abril. No matter how hard I wished to engage into a U-turn, it was not possible. I had to completely cross the Bridge 25 de Abril, and then go to Almada, and only after this huge detour, did I finally manage to head back. After several unnecessary miles, I arrived at the initial road intersection and followed my intended destination. As it happens, on the detour you are speaking of, these are not wasted miles, we are speaking of seventy years elapsed!

- There is, in fact, a certain resemblance, Lucius, between what you have told us and what happened in quantum mechanics – Argus remarked, regaining the subject he was unfolding before Lucius’ appropriate intervention.

– I have to point out, forcibly, that this new nonlinear and causal quantum theory is able to describe the same phenomena as orthodox quantum mechanics does, but now in causal terms and in the conceptual frame work space and time. Thus, we have arrived to a situation where quantum phenomena can be described, either in a causal way, that is, in an understandable and intuitive way; or in indeterministic non causal and non local terms.

We are in a situation rather similar to what happened in Galileo’s time. Back then, there were two theories to explain the planets’ movements. The geocentric model of platonic origin, which Claudius Ptolemy had perfected in the 2nd century of our time; and the heliocentric model of Aristarchus, later regained by Copernicus.

From a formal point of view, as we know, both models were effective. So, they could be used by the astronomers of the time. Its capacity to describe the planets' movements was very similar, considering the precision with which their positions were known then. Naturally, like it happens with all models that intend to describe something real, those models had imperfections and flaws here and there. However, the defenders of such cosmologic models considered these imperfections to be temporary and they believed that future developments would be able to remove them.

We know that the transformation of geocentric cosmology into heliocentric cosmology, accepted by most of the community, both scientific and non scientific, was due to the acceptance of the ontological unification of the sub-lunar and supra-lunar worlds. This change is on one hand partly due to the discovery of new observable evidence by Tycho Brahe and also Galileo, with the aid of the lunette, an observation instrument that at the time had recently been discovered.

The new nonlinear quantum theory comes from a unified vision of the quantum world and the macroscopic world. It shows that the separation of local characteristics and non local characteristics, that is, of the corpuscular characteristics and the undulating characteristics that we adopt in macroscopic physics are mere approximations. These approximations are only valid at that level of description of phenomena. In reality, those characteristics are omnipresent, at the macroscopic level and in the quantum level but only in the latter case do they stop being considered individually; that approximation is no longer possible.

The difference between the situations mentioned before, related to the emerging of a heliocentric cosmos and this new situation lies in the fact that it is now absolutely necessary to find experimental evidence that allows us to decide which theory can describe the quantum phenomena more approximately and more effectively. In confrontation are the Bohrean theory, the so called orthodox quantum mechanics accepted by most of the scientific community, and the causal theory, the nonlinear theory of a second order physics.

- The discussion is reaching a point that seems essential to me – exclaimed interested Lucius – Is there currently any experiment, experiment results, in sum, any experimental evidence that allows us to decide with security which theory should prevail?

Argus smiled and continued:

-That is exactly what I am going to speak about later! But before answering your question I would like to mention, even if just briefly, the recent discovery of super-microscopes. This is the name given to all the family of microscopes that have a high resolution power.

- What is the high resolution power of a microscope? - asked Amadeus.

- I can explain – answered Argus and continued:

- The optical systems for amplifying, like the microscopes, have a maximum theoretical limit for their power of amplifying an image. At first sight, this affirmation may seem like a paradox. In reality, certain people less informed about physics may be led to believe that the capacity of a microscope amplifying an image has no limits. The reasoning that can lead to this naïve conclusion is more or less the following: let us consider an object whose image we want to amplify. Using a common microscope we can amplify the image by let's say one hundred times. This amplification can be easily obtained with a normal microscope. After this, we get the image of the object, amplified one hundred times and we will use it as an object, amplifying it another one hundred times with the same microscope. This second image corresponds to an amplification that is the product of both amplifications. This means, one hundred times one hundred which makes ten thousand. That is, we would have an image with a final amplification of ten thousand times. This process could go on indefinitely, thus being possible to obtain, according to this line of thought, the intended final amplification. However, Nature does not work this way! All the previous reasoning is wrong, or rather, although correct from the logical point of view it is not valid to describe what is going on.

In fact, all the usual systems of obtaining an image have two types of limits in their power to amplify.

One of these, the easiest to understand is related to the fact that the image degrades with successive amplifications. In this way, after a certain number of amplifications the final image is so degraded that it has no use. This natural degradation process results from the imperfections of the lenses and other different causes, which lead to a progressive loss of quality in the final image.

The other limit, a lot more important than the loss of image quality by progressive degradation was discovered by physicists in the 19th century. They discovered that there was a basic and fundamental reason, inherent to all optical devices that lead to an inexorable loss of their capacity to amplify an image. As perfect as the optical instrument may be, this limit always exists.

To this limit they gave the name of resolution. In these conditions, the resolution of a system, optical or not, destined at giving a final image represents the capacity of the system for being able to distinguish, that is, to resolve, two points of the object that are next to each other. This concept is not, in general, very well defined. Now, being somewhat artificial, only in certain cases it is well defined: however, and apart from all its limitations it is an extremely useful concept in practice. This characteristic, that limits the resolution capacity of optical systems, results from the wave nature of light. So for this important concept to be understood, lets us briefly look at how one of the most common optical systems works: the camera. The dark camera, that constitutes a fundamental element of all cameras, analogical or digital, was discovered in the 12th century by the great Arabic scientist Ibn al Haitham, most well known in medieval Christianity as Alhazen. The basic principle of the dark camera can then be represented - and draws (Fig. J6.5).

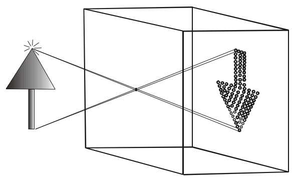


Fig. J6.5 – Scheme of the dark camera

A luminous point of the object that in this case is the arrow, emits light in various directions, however, only a fraction of it, a quite narrow cone, enters the orifice of the camera. This cone of light, representing the luminous point continues until it reaches the screen where it gives rise to a luminous spot. This luminous spot corresponds to the representation of the luminous point object. The other different points of the object in the same way give rise to other image points as you can see. We then have an inverted image of the object. This is the reason why photographers of the epic years of photography had to have a lot of practice to be able to take good pictures. As they saw the object inverted, the setting and focus of the image demanded extra care.

As you can see in the drawing, the orifice diameter of the light entrance in the camera defines the precision, the resolution of the final image. The smaller the diameter of this orifice is the smaller the image point in the target detector will be, and thus more points can be distinguishable, that is, resolved. So, to increase the resolution of the dark camera we would only have to decrease the orifice diameter for the entrance of light. However, in Nature things are not that simple. In reality what we can see is that when the diameter of this orifice reaches a certain minimum dimension, the luminous point that you can see in the target, instead of a decrease of diameter it increases. This fact is due to a characteristic of wave nature of the light called diffraction.

Abbe, a physicist of the 19^{th} century, showed that the maximum theoretical resolution of a microscope was about half a wave length of the light used in the observation. His work was based on a practical rule established by another physicist of his time called Rayleigh.

By the way, I also wanted to add for Liberius' benefit, who is always interested in the latest technology, that this dependency on the resolution of optical systems with the colour of the light used in the devices has enormous technical and industrial repercussions. This dependency between the light used and the resolution of an optical system explains the considerable investments that are currently being made to produce compact disc players and recorders, DVDs and others that use blue light or, even violet light. This effort is perfectly understood if we take into account that the red light used in the present devices has a wave length that is about two times higher than the blue light. The result of this fact is that the devices that use blue light have a resolution power that is about two times higher than the devices that use red light. As a consequence of this higher resolution we have about a fourfold increase in the capacity to store information. To get an idea of the practical and economical implications you only have to see that if it is possible to save two hours of film on a DVD written with red light, on a DVD written and read with violet light you can save up to eight hours of film.

To better illustrate this important question of the undulating optics let us consider this image:

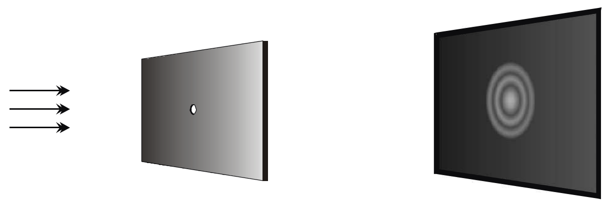


Fig. J6.6 – Image produced by a circular opening in a remote field.

In this scheme we have a screen on which we have made a circular orifice. Further away there is a target on which you can see its image in a remote field. The term remote field means that the target was placed sufficiently far away from the luminous source, from the orifice, so that the mathematical description of the final image is relatively simple. In fact, in these conditions, in the so called approximation of Fraunhofer, this image is relatively well described by the Fourier transform of the circular orifice. In this drawing you can see that due to the wave character of the light, the image of a circle gives origin to a circular maximum of light followed by dark and luminous concentric rings, the diffraction rings, of decreasing intensity.

Let us now make a slight change to the previous scheme, opening another orifice similar to the one before but relatively apart from it, as you can see – and he draws a new picture:

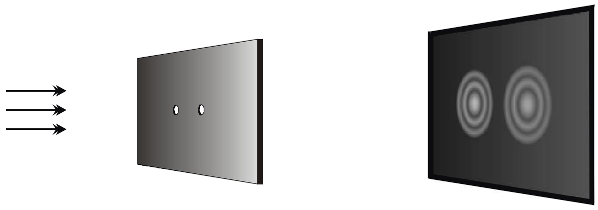


Fig. J6.7 - Image in remote field of two orifices quite far apart.

As it would be expected, the image produced by these two luminous circles, in the target detector, is also composed of two diffraction figures well apart. However, the question I would like to ask now is the following: What do you think happens when the two points of object light, the two orifices, draw close to each other?

- Taking into account what you said – said Lucius in advance – I think the answer is obvious. As the points draw closer, the diffraction spots also draw closer, in such a way that from a certain minimum distance, they seem to be one undistinguishable spot. I think you get something more or less like this – he draws a scheme (Fig. J6.8):

- That is exactly the answer! I can see that you understood the question perfectly – answered Argus pleased.

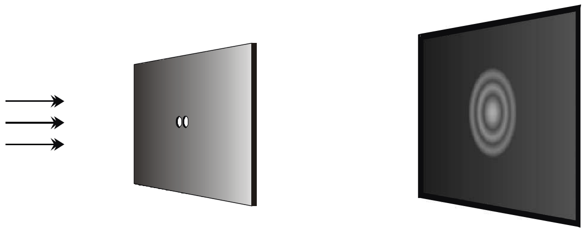


Fig. J6. 8 – Remote image of two very near points.

Meanwhile Argus continued:

- From these experimental facts we can take a practical criterion of resolution of the two object points, like Lord Rayleigh did more than one century ago. Two points are resolved, are separable whenever they give rise to two distinguishable diffraction figures in a remote field. Under these circumstances a practical criterion to infer from these results is that the maximum intensity of a diffraction spot coincides with the minimum of the other one, as you can see in this scheme where a cut of intensities of two diffraction figures is represented – and he draws:

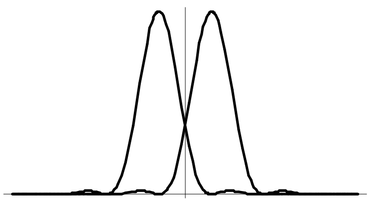


Fig. J6. 9 – Practical criterion of separation, of resolution, of two points.

From this criterion, as I have mentioned before, Abbe determined the maximum theoretical resolution power of a microscope in about half a wave length of the light used.

Since this question about microscope resolution has been clarified I think it is time to go back to super-microscopes.

Until a few years ago the only process of observing the microscopic world was through common microscopes, also called Fourier's microscopes. However, in the second half of the eighties of the 20^{th} century this panorama was radically changed. This change was due to the development of a new generation of microscopes – the super-microscopes – with a resolution power much higher than common microscopes. The practical resolution of these super-microscopes, contrary to Fourier's microscopes, does not depend intrinsically on the wave length of the light used. Moreover, the practical resolution of these new microscopes, as far as we know, has no intrinsic theoretical limits. In these conditions, its resolution can be any, only depending on the technical and practical impossibilities of the systems.

On the other hand, the development of this new generation of microscopes led to a new and ample conceptualization of the systems aimed to produce images. Now that we have gone one step forward, we can certify with certain pleasure that the first devices operating mainly according to this principle, that is, according to different processes from that of Fourier, turned up a lot earlier than it was thought.

In truth, the old and familiar stethoscope, used by doctors for diagnosis, constitutes one of the first systems based on this principle. This medical observation device is capable of locating the heart of the patient with a precision of about ten centimetres. This localization is done by moving the stethoscope along the chest of the patient and listening to the heart beat. The sound frequency for this case can be estimated between 30Hz and 100Hz, which corresponds to the sound waves of about 100m of wave length. If this observation instrument followed the rule of half a wave length for its maximum theoretical resolution, derived from Abbe for Fourier's common microscopes, then the doctor would not be able to locate the heart of the patient. According to this rule, the maximum limit, the theoretical resolution, would then be of half a sound wave length, that is, approximately 100/2 = 50 m! However, you can see that the real resolution of this observation instrument is of about 10 centimetres. This corresponds to a concrete resolution of a wave length divided by one thousand, so it has a resolution about 500 times higher than the maximum theoretical limit of Fourier's microscopes.

The development of these super-microscopes was due to the study of a rare and in a certain way not well understood physical phenomenon commonly called tunnel effect. This phenomenon was discovered when the conditions for certain nucleuses to emit alpha particles were being studied. Due to its rareness and little application in practical day-to-day situations, for a long time this phenomenon was nothing more than a mere scientific curiosity.

At this moment Amadeus intervenes:

- I don't know if it was in a magazine, in a newspaper, or somewhere else, that I read something about a mysterious quantum effect that they call tunnel effect. This tunnel effect, from what I gathered, would have quite strange properties related amongst other things to journeys to the past. If it isn't asking too much, I would like you to say something on this topic.

- I would be very glad to accept your request, Amadeus – answered Argus – so much so that I have been particularly interested in this subject.

The so called tunnel effect, as I mentioned, was discovered in the study of some quantum mechanical applications related to nuclear processes. So as to make this subject clearer let's start with some classic considerations.

Let us suppose that a tennis ball is hurled against a wall. What you can see is that after hitting the wall, the ball jumps and bounces back again. This same fact can be described in a more scientific language. So, we would say that a certain particle, the tennis ball, having a certain kinetic energy, falls on a certain barrier of potential, in this case the wall. As the energy of the particle, the tennis ball, is a lot inferior to the energy of the barrier, the particle is reflected and bounces back.

Let us now suppose that the same experience is repeated, but instead of using tennis balls, we will use a tungsten projectile shot by a cannon. What happens in this case is that due to its great energy, the bullets of this heavy metal go through the wall as if it were made of paper. Going back to a more scientific description we would then say that the energy of the incident particles is higher than the barrier energy; in this case, the bounding energy the wall.

The conclusion to take from these experiments is that, in classic terms, a particle only goes through a potential barrier, when its kinetic energy is higher than the barrier energy. These schemes illustrate this situation – and he draws the following two pictures:

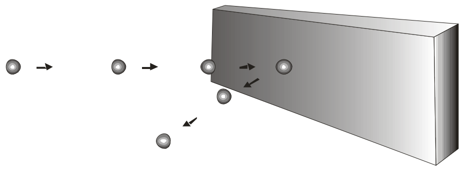


Fig. J6. 10 – Classically, a particle of lower kinetic energy than that of the barrier cannot go through it.

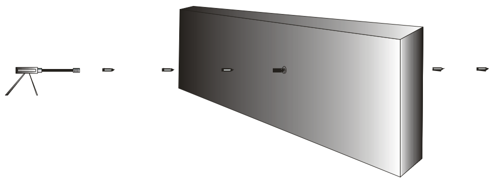


Fig. J6.11 – Classically, a particle goes through a barrier if and only if its higher kinetic energy is higher than the wall connection energy.

However, from a quantum point of view, where we must consider the dual basic unit, the wave-corpuscle entity, things are quite different.

Let us resume the same experiment, but now the particles are quantum instead of classical particles; electrons, for example. In that case, something surprising happens at first sight. Let us imagine that the source issues electrons at a slow but constant cadence, with an energy inferior to the one of the barrier with which it will clash. We can verify that part of the electrons will be reflected, bouncing back, as might be expected. However, an unexpected event occurs. From the opposite side of the barrier we can also observe some electrons. Against everything that might be expected in classical terms some of the beaming electrons had in fact crossed the barrier - he then draws a new scheme, Fig. J6.12

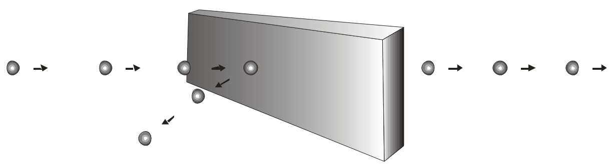


Fig. J6.12 - Tunnel effect. Even having an inferior energy, the quantum particle has a possibility of crossing the barrier.

This happens mainly due to the quantum entity's wave nature. In fact, a phenomenon which is quite similar to the tunnel effect was already known in the wave optics domain. It is the so called frustrated total reflexion.

To explain the situation better, let us see what happens when the light goes from an optical medium to another. For example, from glass to air. What usually happens is that a part of the incident light is reflected while the other is transmitted, as indicated by this drawing (Fig. J6.13).

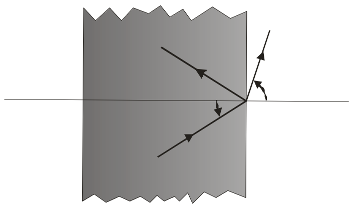


Fig. J6.13 - Light propagation in two optical medium.

As we can see, when the light goes from one medium -. glass - to another, - air- with a lesser refractive index; that is to say, when the light goes to another medium where the velocity of propagation is greater, the angle made by the transmitted ray relative to the normal one at the separation surface between both media is greater than the incident ray. In this case, the ray of light is displaced from the normal. If we progressively increase the angle made by the incident ray with the normal, we arrive at a point called critical angle, from which all incident light is reflected. For angles superior to the critical angle all incident light is reflected. This phenomenon, where all incident light is reflected, is called total reflexion – and he makes a new scheme to illustrate this situation (Fig. J6.14).

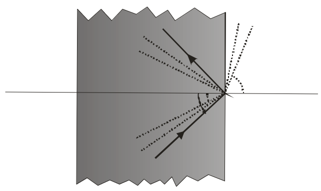


Fig. J6.14 - Total reflection.

As you know, this is the basic phenomenon that goes on in optical fibres, used mainly within the communications' field. However, as always, things are a bit more complicated than they seem to be. Generally, nature proves to be richer and more complex than anything our rough simplistic models make us believe. In this case, we verify that under certain circumstances, even insuring from the start that all the conditions for total reflection are present, there is, in reality an observable transmission of light. In given conditions, light penetrates the forbidden medium! That is precisely the phenomenon which they have designated, inadequately in my opinion, frustrated total reflection. This strange phenomenon is perfectly described, in mathematical terms, by the wave theory of light. Being a consequence of light's wave nature, it is completely similar to the tunnel effect in quantum mechanics, it too being of an intrinsic wave nature.

If photons and other quantum particles cross a barrier in tunnel-type conditions, the issue that now arises is to know the velocity of such a crossing. Surprising as it may be, the calculations lead to a barrier crossing at an immense velocity. The crossing of a tunnel barrier, in certain conditions, happens with an instant transmission time, that is to say, with an infinite velocity.

In my opinion, since I do not believe in instantaneous interactions at a distance, I think such results must be prudently considered. They are a consequence of using an incomplete and surely limited formalism. In reality, this is probably a phenomenon where a change in scale occurs, a phase transition, where the true propagation velocities are billions of times superior to the speed of light.

Now, as it happens, there are experiments to determine the propagation velocity in tunnel conditions which provide such amazing results, to say the least. First of all, it is important to refer that these experiments, which were performed over and over again in numerous laboratories around the globe, all provided the same result. The result is the observation of the existence of the so called superluminal velocities, velocities superior to the speed of light. The quantum system, the particle in question, crosses the barrier at a velocity which is superior to the speed of light.

Let us concretely analyse these experiments in order to make a safer judgement – he starts drawing a scheme:

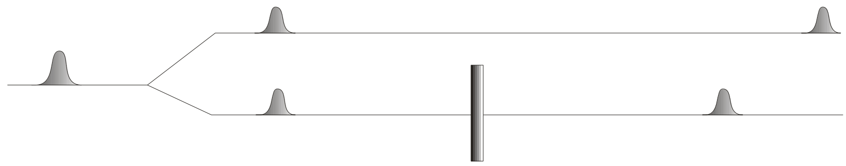


Fig. J6. 15 - The impulse of the light crossing the piece of glass arrives after the one which crosses air.

As you can see, a source emits a luminous impulse which is then divided into two impulses, each of them travelling an equal extension. In one of these courses, the one above, the light only crosses air. The other path has, somewhere, an optical medium, a piece of glass for example. We can verify, through this experiment, that the luminous impulse travelling through air reaches the target detector faster than the one which crosses the optical medium.

From this observed fact, the posterior arrival of the impulse crossing an optical medium, a piece of fibre glass, for example, everyone may correctly assume that this result means that light travels slower in optical fibre than through air. The conclusion drawn from this experiment is that the speed of light travelling in glass is inferior to the speed of light travelling in vacuum.

Let us now see a similar case, only optical fibre is now replaced by an equivalent optical medium, a tunnel barrier, as we can see here – and he draws a new sketch

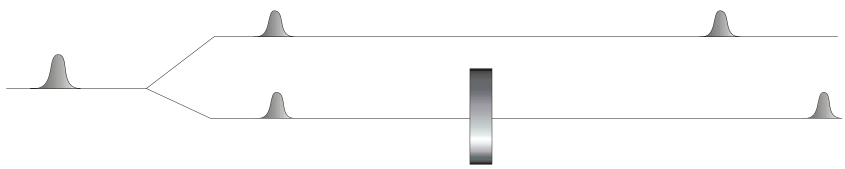


Fig. J6. 16 — The light impulse which crosses the tunnel barrier arrives before the one travelling through air.

The result of this experiment, against what might be expected, is that the impulse following the path below, where the tunnel barrier is located arrives before the impulse travelling only though air. As I said, all the experiments of this kind, and there have been many throughout the world, have always provided the same result. The impulse following the tunnel barrier arrives before the one travelling through air.

If we applied a similar reasoning to the case where the medium was optical fibre, the conclusion would be obvious and it would indicate that light travelled faster in the tunnel barrier than through air. I mean, inside the tunnel barrier we would have the superluminal velocities.

However, this is where the problem is, since this conclusion is contrary to one of the postulates of the theory of relativity which claims that the maximum possible velocity is *c*, that is, the velocity that light reaches in vacuum. Most authors have tried to demonstrate that the results of these experiments are not in contradiction with the theory of relativity. Thus, trying to take advantage of Fourier's nonlocal and nontemporal ontology, they try very hard to question the conclusions drawn from the experiments' results. As we have previously seen, in Fourier ontology only one harmonic plane wave has a well defined velocity. In these conditions, any finite impulse always derives from the compositions of many infinite waves in space and in time, each with its own velocity. This is how the magnum problem of defining the velocity of a finite impulse arises. Consulting scientific literature on the subject, we can verify that there are almost as many definitions for the velocity of a finite impulse as authors who have dedicated themselves to the matter.

In these conditions, using an "adequate" definition of the velocity of a finite pulse we conclude that, after all, the early arrival of the pulse from the tunnel barrier would not implicate a velocity superior to the one going through air.

The reference Amadeus made to the so called violation of the past, and consequently, of the the causality deriving from these superluminal velocities, results from the following reasoning. First of all, I must say I have heard people who consider themselves qualified in relativity, making exhibitions and seminars where they have demonstrated that the existence of superluminal velocities implicated a violation of causality, of an action in the past and so on. Unfortunately, even some contemporary literature of negative scientific information falls into this same mistake.

Let us see how these authors arrive at this astonishing consequence:

First, they assume as a starting point that the theory of relativity is valid, not only to describe the conceptual experimental Universe in which it was conceived, but also to describe every physical experiment that mankind will discover or develop in the near or far future. According to these expert authors, the theory of relativity is, and will always be, the first and the last word. This completely dogmatic assumption is entirely contrary to a true scientific spirit. Unfortunately, such an attitude is not uncommon within the scientific community. It suffices to remember that in the 19th century, Lord Kelvin, along with many other good men of science, believed and shouted out loud that science, the physics of the time, was a perfect and concluded building. There was nothing left to do, besides enhancing details and their respective practical applications. We know that the 20th century has shown us how vain and deprived of meaning such an assumption really was. Precisely responding to the explicative incapacity of classical physics regarding microphysics phenomena, quantum mechanics was born. In the domain of phenomena where huge velocities intervene, where the speed of light is involved, relativity was born.

Probably, these people who sought to be side by side with those who held power in their evaluation, instead of searching for the scientific truth; and who now dogmatize, I shall say even more, who now deify the theory of relativity, presently so fashionable, they would be the first ones to fight Einstein when he elaborated on the theory.
As we know, one of the assumptions, one of the basic postulates of the theory of

relativity is that the maximum possible velocity any material body can achieve is *c*, that is to say, the velocity of propagation of light in vacuum. Now, relativity, being a good project of a scientific theory, necessarily has to be coherent with its own postulates. Thus, once we introduce a strange element in this theoretical building, in perfect antagonism to all its logical system, we cannot expect a worthy answer in the end. Indeed, the strange element being introduced is, to say the least, hideous. It consists of admitting that in certain experiments, in tunnel conditions, photons travel at a greater speed than the speed of light in vacuum. Since these results are radically against one of the basic postulates of the theory, if there can ever be an answer, it will have to be completely without meaning. Something similar to what happens in a well lubricated machine when, for example, in the engine of a well tuned car, someone inadvertently or not pours an adverse ingredient instead of the adequate fuel, like sand or another abrasive. The final result is well known to us. The whole system, the machine, convulsively collapses until it no longer works. I do not know, ho Amadeus, if I have answered you question properly. What do you say?

- From the way you clarified the problem, I think there is little doubt left. I will say even more, anyone who is scientifically honest, and who has reflected a little on that problem not confusing the whole with the parts, would see that the structure of the theory of relativity does not bear velocities superior to the speed of light. Which is rather obvious, since one of its postulates consists precisely in denying such possibility - answered Amadeus.

- That was precisely what I intended to say - replied Argus. – If the superluminal velocities in fact exist, as we are led to believe, that can only mean that the theory of relativity needs to be reformulated, generalized, in such a way as to include, in certain cases, velocities superior to *c*. Such a conclusion is rather unsurprising, since relativity is a century old, and therefore, from its elaboration to the present day, a lot of work has been done, either conceptually, or regarding the development of new instruments that allow us to perform new and much more precise experiments. After all, the so called theory of relativity, like all other physical theories, is but a human creation, and consequently, it is necessarily limited. As I previously mentioned, wanting to see the theory of relativity as the final truth, the last word in the explanation of natural phenomena, is not a scientific attitude. At the most, it is only a dogmatic belief similar in nature to religious beliefs.

After this detour, I will return to our initial subject of the last generation microscopes, the super microscopes. It was during the 80s of the 20th century that Binning and Roher, two researchers working for IBM, developed the tunnel effect microscope. Soon after, in 1986, they won the Nobel Prize for this discovery. As the name clearly shows, the base principle of this microscope's functioning was the tunnel effect we have been discussing.

The electronic tunnel effect microscope is formed by a small tungsten needle with a tip worked with such accuracy that its extremity could be one simple atom. This sensor, the tip of the needle, is mounted on a set formed by piezoelectric quartz crystals, in a way that it is capable of scanning the whole sample to be observed. The tip of this needle is manoeuvred at a very small distance relative to the conductive sample. Actually, only about 1 or 2 nanometres. I remind you that 1 nanometre represents 1/1 000 000 000 of the metre, that is to say, 1 metre divided by a billion! When a small electrical tension is applied to the tip of the needle, electrons, due to the tunnel effect, overcome this separation originating a minute electrical current. The intensity of this current depends exponentially on the distance separating the tip of the needle from the preparation. As this sensor sweeps through the preparation, line for line, the intensity of the electrical current will also change according to the distance between the point of the needle and the preparation surface. These variations of intensity of the electric current are injected into a computer, which, after an adequate treatment of the information, produces an amplified image of the sample surface that is being observed. Here is a rough scheme of this microscope:

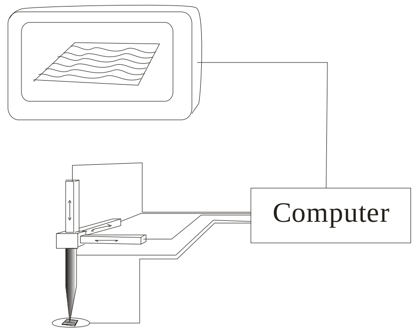


Fig. J6.17 – Microscope of tunnelling effect.

These super-microscopes allow the possibility of obtaining images with separate points of about 0,2 nanometres.

After a little while the same principle was generalized to other domains, giving rise to a new generation of super-microscopes. The first development was done to overcome one of the biggest limitations of the microscope of tunnel effect. This limitation consists in its restriction in only producing images of conductive substances. This effort gave rise to the atomic force microscope. In this microscope, the tungsten needle is substituted by a diamond point. Instead of the small tunnel current, the point is sensitive to the forces of Van der Waals. These forces are produced when the distance between two substances is very small.

Just so that you get an idea of the value and importance of these forces you only need to know, for example, that two pieces of glass with surfaces with the same shape and perfectly polished, when leaning against each other, get so attached that it is impossible to separate them, as if they had been glued together with some very strong glue. The “collage” of these pieces is due to the forces of Van der Waals.

In these conditions, the small variations in the force felt by this point when it passes over the sample are then supplied to the computer system for the treatment of information. After proper treatment of the information collected by the computer system, the amplified image appears on the monitor or on any other display device.

- Argus, I think that system of producing an image of an object is a little strange. The whole process seems to be quite complicated – intervened Amadeus.

- You are totally right – answered Argus. – To properly clarify this situation I think it is best to handle the subject with a bit more generality.

In the common Fourier’s instruments of image obtaining, that means, in the image systems, the information originating from the object goes into the optical device in the form of a luminous wave. In this device the information is treated giving rise to a relatively faithful reconstruction of the initial object. To simplify the analysis of this question let us consider firstly one of the simplest and oldest amplifying devices, the common amplifying lens. This instrument, as you know is in general composed of a simple converging lens or even by a round water vase, like for example a small fish aquarium. In any of these cases, after receiving the luminous information of the object this instrument gives rise to, depending on the situation, a virtual or real image that may be recorded on a physical device.

In this case and in other similar cases the information originating from the object is treated directly by the device without any direct intervention of the observer. The imaging device works like an analogical system specifically built for that end. If the shape of the lenses that compose the device was different, instead of a very reasonable image of the object we would get a final image of the object with little or no similarity to the initial object. So, the final produced image is the consequence of the way the device was built, that is, the shape and the material of the lenses and also the distance at which they were placed. It was precisely because of this that when Galileo presented the first amplified image of the Moon, Venus and Jupiter’s satellites, obtained with the aid of the telescope built by himself, most people, including cultured people did not believe what they saw. They thought that the images seen in the telescope were mere hoaxes, pure tricks, produced by the observation device. In this sense, they did not make a distinction between the nature of the images produced by the telescope and the images produced by other optical systems, such as the kaleidoscope or other devices composed of mirrors and lenses used in fairs and spectacles by illusionists. So that the images produced by the telescope could be accepted as representative of a truly existent object it was necessary, before anything else, to build a whole image formation theory of the devices.

We know Galileo did not have a theory that validated the images produced by his telescope. Without an adequate validation criterion, the images produced by the telescope did not have any meaning. Naturally you could test the lunette on the Earth with distant objects thereby verifying whether the image produced by the device were similar to the real objects. However, it is useful to keep in mind that this validation only made sense for earthly objects. For celestial objects such a comparison criterion did not have any use, since it was not possible to go to the location to test the validity of the image with the original object. The Aristotle paradigm, at the time accepted by the scientific community, affirmed that the celestial objects had an eternal and perfect nature, totally distinct from earthly objects that were imperfect and perishable. It was therefore necessary, as Galileo knew all too well, to change this entire dichotomist paradigm so that the images produced by the telescope could be accepted as true by the scientific community.

- I have finally understood – exclaimed Lucius – the reason why many knowledgeable people and I would even say honest people, did not believe Galileo's observations. Any minimally cultured person that lived at that time accepted aristotelic cosmology a lot more easily, not only because they had been educated on it but also because it seemed a lot more understandable than the dubious and foggy images produced by Galileo’s telescope.

- Since the final image is obtained by a direct and relatively simple method – continued Argus – in this case and in other similar cases, we can call this global process, a measurement, or an observation of the first kind.

The functioning process of the new generation of super-microscopes is a lot more complex. In these devices the final image is obtained after a long and hard work. The collected information on the specimen to be studied by the sensor is sent to an “intelligent” system, a computer that processes that information in accordance to a program. In general, the code of programs for treatment of the signal reaches great levels of complexity, in such a way that, even with the high speed of current processors the information processing can take a considerable amount of time to produce the final image of the object. The program has to take into account the physical processes underlying the different interactions that occur during the measurement. On the other hand, it should also take into account the scanning mechanism, the systematic and random errors, weigh up the relevant factors so that at the end, after the rendering, smoothing, and the respective colouring is done, it produces a reasonable image that can be seen on the display or that can be printed. It is best not to forget that to be able to obtain an amplified image of the specimen, the device needs to be associated to a retro-feeding system, a feedback that is, an auto-regulation system: a system that reacts in relation to the response. This system should be involved in the whole measurement process, from the specimen being observed to all the constituent parts of the physical device, from the microscope to the processing information system. In these conditions, the "intelligent" system establishes, according to an iterative method, the best interaction process between the specimen to be analyzed and the device, in order to obtain the best final possible image.

In most medical imaging systems the global process for obtaining the final image is in everything similar to the one used in the super-microscopes. For example, in magnetic resonance images or computerized axial tomography, the programs that process the information collected by the sensors work as a system that allows choices, that asks questions, even offering suggestions for the best procedures.

The ultra-complex computing program of these new imaging systems processes the information collected by the sensors and also takes into account the overall behaviour of the whole system. The global functioning of these systems gives rise to an observation process that is highly complex. This measurement process is, as you can see, a lot more complex than the direct process, or first kind process, undertaken by Fourier's systems, where the observation is done directly. For that reason it is natural to name these more complex observation processes as second kind measurements. As I have already told you, in these second kind measurements the measurement device behaves as if it has a type of rudimentary intelligence, in such a way that the final image significantly depends on the programme of treatment of the information obtained.

At this moment Lucius intervenes:

- What I gathered from what you have said is that observations can group up into two big categories: we have simpler and more direct observations, or of Fourier, that you called first kind measurements but on the other hand we have the second kind observations that are lot less direct. In these, there is a whole extremely complex treatment of information that originates from the object. The final image of the object is only built after a long and hard process of analysis, synthesis and I would even say conjecture.

- That is exactly what I intended to say – exclaimed Argus – The principle of the tunnelling scanning microscope was extended to the optical field, giving rise to a whole set of imaging systems capable of exploring the optical properties of the specimens. The first of these instruments was developed in 1984 by a group of investigators led by Pohl. Also in this case they were technicians from IBM. The resolution of this first optical super-microscope was of one wave length divided by 20. Today, due to special techniques of illumination and other technological tricks, you can get resolutions more than five hundred times higher than those of the common Fourier's microscopes.

To simplify things I will only mention the basis of one of the most simple of those instruments. Even so its practical resolution is about 25 times higher than that of the common Fourier's microscopes.

Since this microscope, like all of that generation, makes second kind measurements is then composed of a material or instrumental part and a part of non material nature, "intelligent" nature: the information treatment program. The "intelligent" system receives and processes the information at the same time as it properly controls the necessary mechanisms of interaction between the different parts of the microscope. As I mentioned, this computer program is, in general, very complex.

The material part, strictly speaking, of the microscope is composed of three basic elements:

1) An extremely small sensor that catches the light emitted by the object. In some of these microscopes, with a resolution of 10 nanometres, this light sensor is composed of an optical fiber. This optical fiber has the shape of an extremely sharp needle with a light caption area that is smaller than the width of a strand of human hair. The size of the area of light caption is, as you probably understand, a critical element in the final resolution of the microscope.

2) An illumination system. In some types of optical super-microscopes with a resolution in the order of the nanometre, the critical element is composed of the system of illumination, while the dimension of the area of light caption is not as important. In such optical imaging systems, the light source is composed by the tip of an extremely sharp needle. The resolution, in this case, depends significantly on the dimension of this light source.

3) A scanning system. The scanning system, common to all these super-microscopes is in general composed of a system of cantilevers with piezoelectric quartz arms. The application of an adequate voltage on these arms allows the scanning, line by line, of the object area to be analysed. In a few microscopes this scanning system is connected to the sensor that collects the light emitted by the object. In others it is the illumination system that is connected to the scanning device.

In these devices of optical imaging the light collected by the sensor is converted into an electrical current. It is this electrical current that being proportional to the intensity of the light locally diffused by the object, feeds the processing system. This received information allows the creation of a distribution map for the object’s luminous intensity. To get a better resolution, the auto-control device regulates the optimum distance between the area of light caption and the object. In any case, the information received is subject to adequate computer treatment, taking into account the removal of noise, the rendering, smoothing over of irregularities and also the supply of the proper coloration. At the end of all this work, an amplified image of the object appears on the monitor. Some of these final images are really very beautiful, and constitute great works of art. Here is a very simplified scheme of this super-microscope (Fig. J6.18).

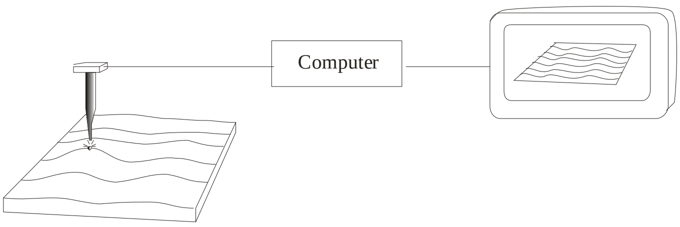


Fig. J6.18 – Optical super-microscope.

As you can see, for simplification reasons, the scanning system was reduced to a small plaque on top of the optical fiber. On the other hand, the illumination device that in some microscopes is critical is not represented here.

In this specific type of microscope, not directly based on the tunnel effect, the resolution depends fundamentally on the light caption area of the sensor, on the distance between the sensor and the light diffusing object point and also evidently on the minimum step of the scanning system.

Due to the fact that this discussion has gone on for a long time and we are all a bit tired I think it is best to leave the concrete proof of the experimental limits of orthodox quantum mechanics to our next meeting.

SEVENTH JOURNEY

This time, as I usually headed towards the Bookshop of the Eternal Return I was excited. I was also curious because I would finally know the experimental evidence that shows that indeterministic orthodox quantum mechanics, a theory that rejects the possibility of pronouncing ourselves on the existence of a reality independent from the observer, is not, as many claim, the last and final word. After all, this theory, like any other from the past, must be subject to very serious limitations in its ability to explain natural phenomena. Due to my great interest in what we were about to discuss I prepared my things so that I could get there early, so much so that I was the first to arrive at the Bookshop. I was already drinking a beer when Fabrus arrived accompanied by Amadeus. After a while Argus and Lucius arrived. After the usual exchange of greetings, Argus started the discussion.

- For about seventy years, men like Louis de Broglie, Einstein, Schrödinger and many others, tried to fight the orthodox interpretation of quantum formalism. As we know, they started from the assumption that there is an objective reality independent from the observer. Naturally, they were conscious that the observer interacts and therefore can change Nature to which it belongs to, to a greater or lesser degree. On the other hand, they firmly believed in the possibility of building local and causal quantum physics. However, from the start they were limited by two obstacles that apparently could not be overcome in this fight. The first obstacle, that I have mentioned, resulted from the implicit acceptance of Fourier ontology. As we know, the acceptance of this ontology, non-local and non-temporal, inevitably implies the adoption of the non locality in space and time, of the indeterminism, that is, of the non existence of causal relationships between phenomena.

The second obstacle, also a big obstacle, was related to the enormous explanatory and predictive capacity of the orthodox theory. We have to take into account that up until 1996 no concrete experimental evidence that could prove the applicability limits of the orthodox quantum mechanics had been put forward. All experimental results, within microphysics, had been described by the Bohrean theory in one way or another.

In these conditions, it was no surprise that the opposition to the orthodox interpretation manifested itself more from the general and philosophical point of view, in conceptual and formal terms, gearing itself towards the great public under the form of the so called quantum paradoxes.

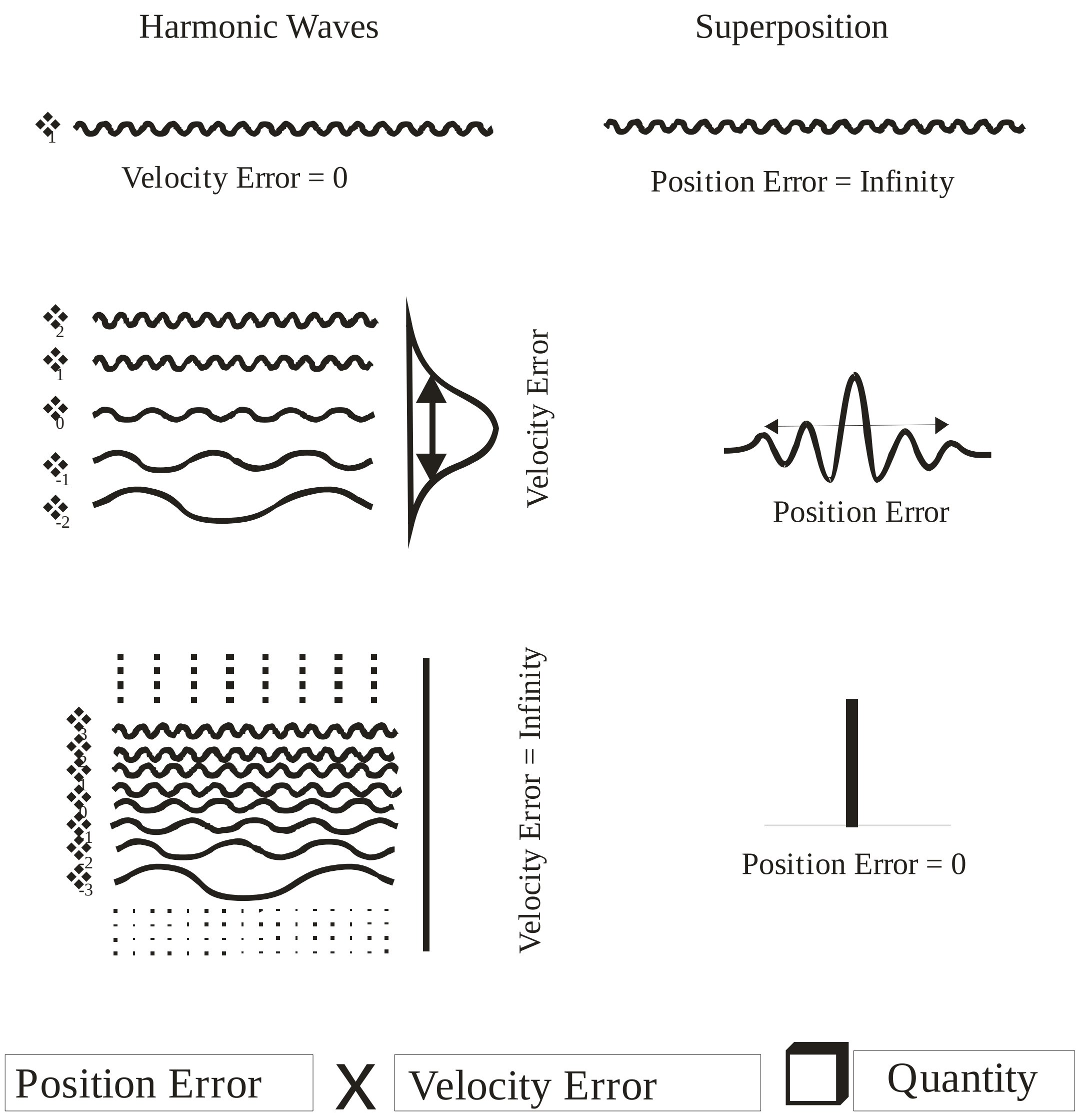
I have already talked about the removal of the first big conceptual obstacle, Fourier ontology. Now what needs to be shown and we shall do this immediately is that the limits of validity or application of this theory have already been found. Moreover, this rupture happened in one of the most important pillars that support the theory, the so called indetermination relations of Heisenberg. As we know, the most adequate name for them would be the Heisenberg-Bohr indetermination relation, because although Heisenberg had the privilege of writing their mathematical expression for the first time, in reality it was Niel Bohr who understood their meaning and attributed them with the privileged status they have had since then.

As I have already told you, in February of 1927, Heisenberg, a young physicist at the time, reached these famous relations and hurried to Copenhagen to show them to Bohr, who had already been awarded the Physics Nobel Prize for his theory on the structure of the atom. Later on, that work gave rise to an article of 27 pages that appeared in a German magazine. This article contained the derivation of the inequality that would later have its name. When Bohr saw the mathematical expression of the inequalities for the first time, he was very excited. However, he disagreed with the interpretation Heisenberg wanted to give them. Heisenberg, who had worked in the School that had created matrix mechanics, intended to interpret them only in the framework of a general mechanics where the wave characteristics of quantum entities were absent. Bohr realized that these inequalities could not be interpreted in such a simplistic way. They would have to be interpreted considering both the corpuscular and the wave characteristics. Heisenberg felt undermined by Bohr and it is said that he left that meeting very downtrodden, maybe even crying. As I have already mentioned, between February and September of 1927 Bohr meditated on the meaning of the relations that Heisenberg had presented to him. Bohr knew that the year before, in the framework of his quantum mechanics where the corpuscular characteristics were absent, Schrödinger had shown that is was possible to describe the quantum phenomena from the equation he himself derived: the famous Schrödinger equation. Moreover, Bohr knew that Schrödinger had shown that the two formulations that are, the matrix mechanics and wave mechanics were equivalent, that is, they described the same phenomena.

During those months Bohr associated Heisenberg inequalities with the mathematical relations derived from Fourier analysis. It was in this way that Bohr had managed to interpret Heisenberg-Bohr relations, in a particularly simple and elegant manner, as a particular mathematical expression of his famous complementarity principle. Bohr presented these ideas to the scientific community for the first time in his famous communication to the Volta Congress, in September, in Lake di Como, Italy, about one month before the famous Solvay Congress of October 1927.

Let us see in summary what Bohr's idea consisted of: as we've seen, from Fourier non-local and non-temporal analysis it is known that when one intends to represent a localized function, for example, a Gaussian function, the narrower it is the larger the width of the necessary band, that is, the bigger the distribution of monochromatic harmonic plane waves that need be added to reproduce it and vice-versa, as you can see in this drawing:

FOURIER



HEISENBERG-BOHR INDETERMINATION RELATIONS

$$\Delta x \Delta v \geq \frac{h}{m}$$

Fig. J7.1 – Heisenberg-Bohr relations.

It is to be noted that Δx and Δv represent the uncertainties, or errors, in the determination of the position and the velocity.

When we have only one harmonic wave, its extension is, as we know, infinite, in space and in time, and according to Fourier ontology it has only one well-defined frequency, either spatial or temporal. This, in turn, and according to the implicit postulate of quantum mechanics, corresponds to a well-defined energy and therefore to a perfectly defined velocity. If in this case we have a well defined velocity (that is, without any errors) what can we say about the position of the particle?

As the particle can be located by the act of measurement in the regions where the wave has a non null intensity and as this wave exists in all space and all time with the same amplitude, one can then conclude that it can exist with equal probability in all space and in all time. So, uncertainty, or the error in determining its position, is infinite. In these conditions our knowledge of the velocity is absolute. The velocity value is known without any error. However, it is also true that the price to pay is enormous. In this case, we do not completely know the position of the particle, since it can be located in all space and in all time.

The second horizontal group of drawings represents the general case in which the particle is represented by a finite wave. In this case it can be located in a certain finite region of space. More exactly, it can be localized in the region where the intensity of this wave is non null. The error in determining the position is due to this zone's size. What then is the speed of the particle in this case? We do not know! All we know is that the finite wave that contains all the information about the particle is composed by the addition of many harmonic waves, each with a well defined velocity. In these conditions, the uncertainty about the velocity of the particle is given by this velocity interval; that is, by the bandwidth of harmonic waves that compose the finite wave.

The last drawing represents the other extreme case: the position of the particle is known without any error. This type of function that has the information about the precise location of the particle is called Dirac delta function. In this case, the bandwidth of the harmonic waves necessary to build this function is infinite and therefore, the error, or the uncertainty in determining the velocity of the particle is infinite.

In sum: the more you can predict the position of the particle, the less you can predict its velocity and vice-versa. The uncertainties in the position and the velocity are inverse variables and are linked through the Planck constant, as indicated in the final equation that expresses Heisenberg-Bohr relations. This way, the product of the two uncertainties is equal, in the ideal case, or bigger than a particular constant quantity. This quantity is equal to the Planck constant divided by the mass.

These facts are, as we have seen a simple consequence of the nature of Fourier analysis. However, I want to bring to your attention a very important point: a lot of people call these expressions uncertainty relations, other times they are called indeterministic relations, even using these words as synonyms.

If we name these inequalities uncertainty relations it means we believe that before the measurement takes place, before the observation, the particle has a well defined position and velocity. If that were so, we would not know its precise value due to a set of merely conjectured circumstances, like the nature of the instruments used in the measurement and the inevitable device-object interaction. In this way and at best we would only be able to establish the value of the respective quantities approximately, with a certain error inherent to all real measurements. In these circumstances, these relations would only indicate our factual lack of knowledge of the true position and velocity of the particle.

This affirmation could eventually be true in the case of us trying to describe the behaviour of a great number of particles. We would in that case be talking about a statistical distribution of velocities of that great number of particles. However, common quantum mechanics, as we know well, is a linear theory. The immediate consequence of this is that what we can affirm about the statistical behaviour of a great number of particles can also be applied when our object of study is composed only of one particle. As such, it works to describe one sole particle as well as to describe many particles. In the case of one sole particle the acceptance of Fourier ontology stops us of talking about a statistical distribution of velocities, since no real particle can have multiple values for its velocity and position simultaneously.

In these conditions, to be consistent with the theory we would forcibly have to name such inequalities as indeterministic relations. It becomes necessary to clearly explicit the fact that in defending that quantum mechanics is a complete theory, it does not make sense to talk about the position or the velocity before the measurement as something real. Before the measurement all we have is a group of potentialities, probabilities without any real existence. Only the measurement, that is, the observation can eventually turn one of the potentialities into reality.

At this time Fabrus commented:

- It is true! Unfortunately, most of the time and a lot more than is thought, people who claim to be defenders of the orthodox quantum mechanics but who never understood it, mix up uncertainty with indeterminism. Uncertainty is something simply factual, while indeterminism stands for a barrier that cannot be overcome and that is intimately related to our cognitive limitations. These people still cling on to the classic thinking characteristic of a pre-quantum paradigm. I was unfortunate enough to hear an illustrious physics teacher, who claimed to be a quantum physicist due to the fact that he taught quantum mechanics at a University, and he pompously stated that quantum mechanics was a causal theory!

Argus started again:

- The success of these relations was enormous! From early on, the scientific community realized its great importance. Since the start many publications appeared, not only in the physics domain so to speak, but also in works of epistemological and philosophical nature. In such conditions, it is not strange that many people, including even certain well-known authors, did not understand its deep meaning properly. For that reason, violations of these relations that in the perspective of the Bohrean paradigm are perfectly irrelevant are sometimes invoked. As always Bohr, Heisenberg and even Karl Popper emphasized that the uncertainty relations are related mainly to the measurement problem, that is, the observation in quantum mechanics and with the predictions that we are qualified to do regarding a future measurement.

To better illustrate this situation, let us consider a case of an apparent violation of the Heisenberg relations. From the possible multiple possibilities we will consider an excellent example presented by Andrade e Silva in the sixties – he starts to draw:

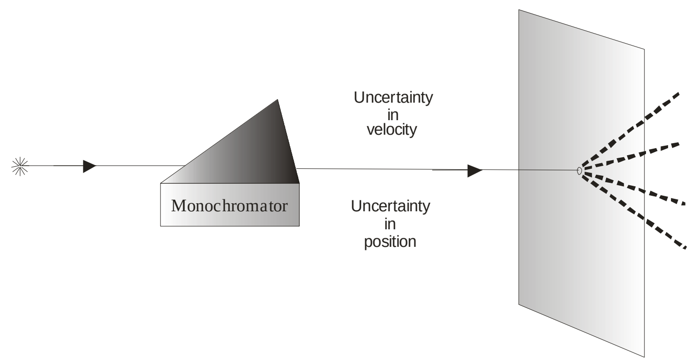


Fig. J7.2. – Experiment on the apparent violation of the Heisenberg relations.

In this drawing you can see a source that emits electrons, one at a time, a monochromator and a target with an orifice, behind which there is a velocity detector. This detector has the particularity that it records the passing of the electron without destroying it. In its turn, the monochromator is a device that works like a prism. When white light falls on a glass prism it is decomposed into the fundamental colours, giving rise to the colours of the rainbow. This results from the fact that white light is the mixture of all colours, from red to violet. The action of the prism is precisely to operate this separation just like a selector sieve. As each colour corresponds to a frequency, this means that the prism will separate the different frequencies that compose the initial beam. In these conditions we can isolate a band of frequencies, that is, of colours, for example, the yellow band. That is why monochromator (mono +colour) is the name for that device that isolates only one colour, or more precisely, that lets a narrow band of frequencies pass.

Then the electron emitted by the source falls on the monochromator coming out of it with uncertainty in its frequency, which is the same as saying an uncertainty in velocity, since these two values are related. This uncertainty in frequency depends only on the characteristics of the monochromator. The product of the uncertainty of velocity by the uncertainty in the position should respect the Heisenberg-Bohr relations. It should then be higher or equal to the Planck constant.

All very well up until here. However, let us suppose that we now make a very small orifice in the target and let us also admit that the detector is arranged in such a way that allows us to attribute an uncertainty a lot smaller than the previous one to the electron's position. As the uncertainty of velocity only depends on the quality of the monochromator and the uncertainty of position of the group detector-orifice, placed on the screen, and therefore these are independent values. In these conditions, it is always possible to choose a good monochromator and a detector-orifice set in such a way that immediately before the interaction there is a value that is a lot smaller than the Planck constant for the product of the uncertainty of velocity by the uncertainty of position.

This result would then apparently be in contradiction with the Heisenberg-Bohr relations. However, when the velocity measurement is done, the electron transfers a certain quantity of energy to the detector. Since this quantity of energy is always undetermined, it then follows that the uncertainty in the prediction of velocity of the electron increases. This increase is bigger as smaller is the error in the determination of the position, that is, as smaller the dimension of the orifice is. Therefore, after the measurement, after the interaction, we know that the product of new uncertainties is equal or bigger than the Planck constant. This result shows clearly that there was no disagreement with the Heisenberg-Bohr relations.

For a conclusion we can say: regarding something that has already happened we can have concrete experimental situations that lead to a numerical disagreement. However, with regards to predictions about a future measurement, due to the inevitable object-device interaction, the uncertainties in the determination of the position and velocity are such that we are once again limited by the Heisenberg-Bohr relations.

- The famous Heisenberg relations or Heisenberg-Bohr relations, as you called them, are not mysterious after all! – exclaimed Amadeus – They are nothing more than a direct consequence of the acceptance of Fourier ontology.

- It is exactly as you say – continued Argus – So, if we reject this ontology we open doors to obtain the uncertainty relations that are a lot more general.

In truth, if we proceed in a manner similar to the one used by Niels Bohr to derive the usual indeterminist relations, but instead of using the non-local and non-temporal Fourier analysis we use the local analysis by wavelets, we get a set of uncertainty relations that are a lot more general – and he started to draw (Fig. J7.3).

WAVELETS

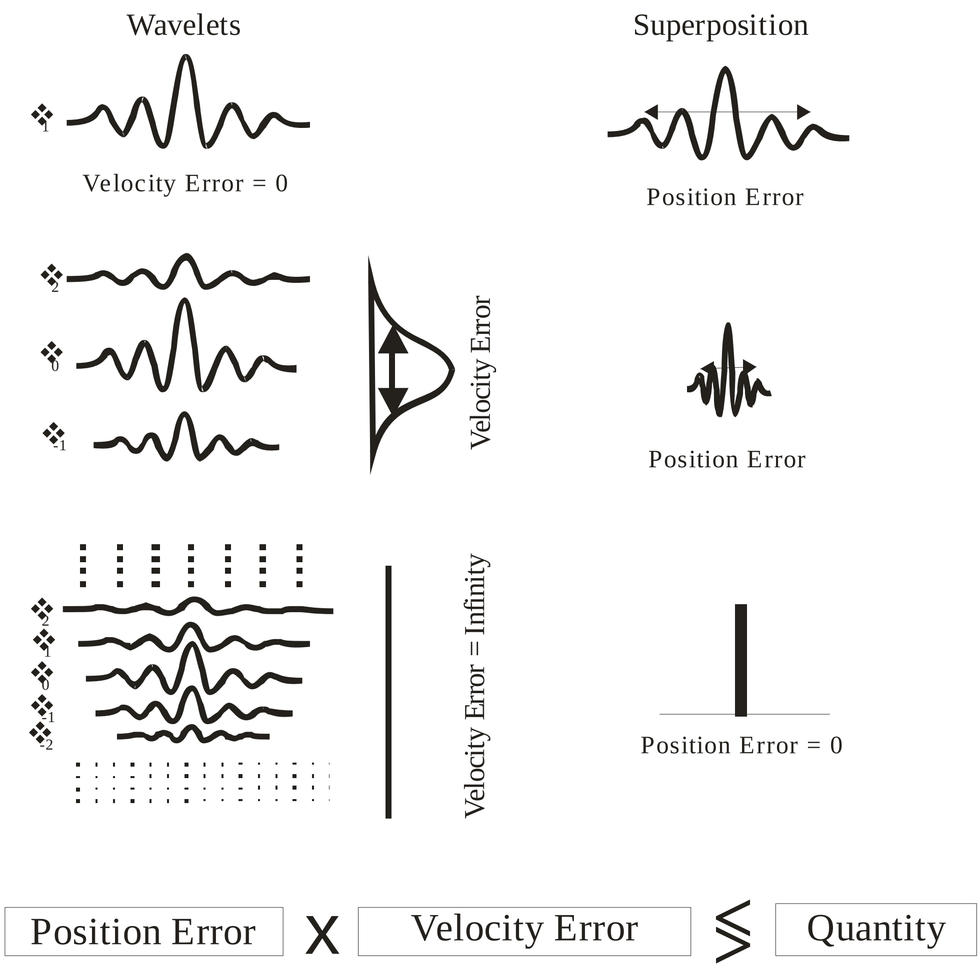


Fig. J7.3 – General relations of uncertainty

As we have seen, if instead of using harmonic infinite waves as a basic element, we use Gaussian wavelets or Morlet wavelets we get more general uncertainty relations. For curiosity's sake I will write down the mathematical formula, which is relatively more complicated than the usual or orthodox uncertainty relations:

$$\Delta x^2 = \frac{h^2 / m^2}{\Delta v^2 + \frac{h^2}{m^2}\frac{1}{\sigma_0{}^2}}$$

In this expression, σ_0 represents the dimension of the basic or mother wavelet. As you can see, if the wavelet's dimension is very big, these new relations become Heisenberg-Bohr relations from the formal point of view.

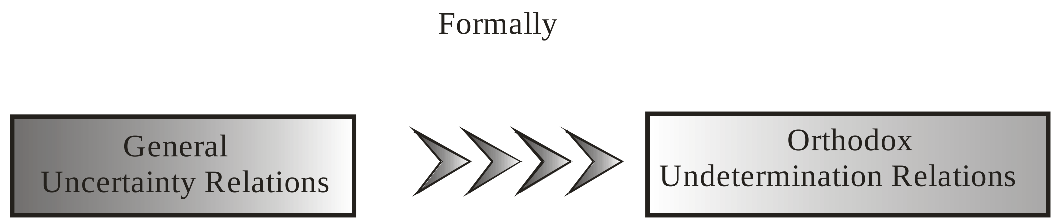


Fig.J7.4 - In the limit, when the dimension of the basic mother wavelet increases, the general relations transform themselves, from the formal point of view, into the usual ones.

In the derivation of the general uncertainty relations the base wavelet used was the Morlet wavelet. This choice was made due to various reasons. Amongst them is the fundamental fact that these wavelets have a well defined frequency. On the other hand, they also have the supplementary advantage that they are relatively easy for mathematical treatment. In this case, the formal treatment can be made in general without resorting to any approximations. This point is extremely important, since when approximations are made to reach a final result, you never know with certainty if it depends on the source theory or of the approximations that were made throughout the calculation. Finally, another advantage of no less importance from the conceptual point of view, results from the fact that from the general relations, obtained from this process, from a purely formal way you can derive the usual relations as a simple particular case. This result is obtained simply by letting the dimension of the basic mother wavelet grow as much as we want, so that on the limit it can be identified practically as an infinite harmonic wave – and he drew:

Fig. J7.5 – In the limit, when its dimension is very large, the Morlet wavelet comes close, for all practical effects, to an infinite harmonic wave.

So that we can see well the difference between the usual relations and the new ones that are more general, in first place we will represent the measurement space of the orthodox relations. Basically, this abstract space of measurement is nothing more than the region where we can make our predictions for the determination of the errors in the velocity and position of a quantum particle in a future measurement, as one can see in the drawing – he drew something new:

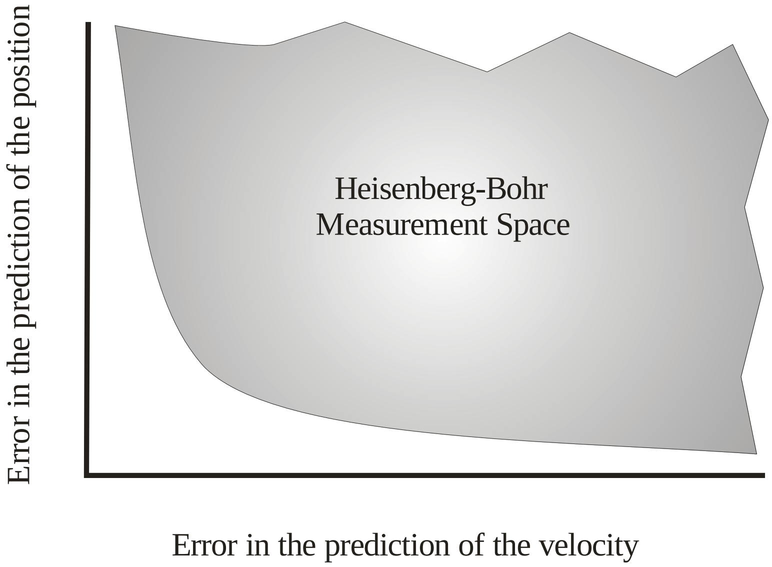


Fig. J7. 6 – Abstract space of accessible measurement according to orthodox quantum physics.

The vertical axis represents the indetermination in position, while the horizontal axle represents the indetermination in velocity. The interior, without shading, not accessible to the measurement, represents the forbidden region according to common quantum mechanics. This region would always be forbidden for us. It is not about a mere factual and instrumental impossibility, but a real theoretical limit, a last unreachable haven in our ability to understand reality. The exterior region, which is shaded, corresponds to the zone in which we can make predictions; it is in that region that we can make predictions about a future measurement. The border represents the ideal case in which inequality converts into equality; it represents, according to the orthodox interpretations, the minimum indetermination that it is possible to reach in any measurement. Let us now see what happens in the more general uncertainty relations – and he started drawing:

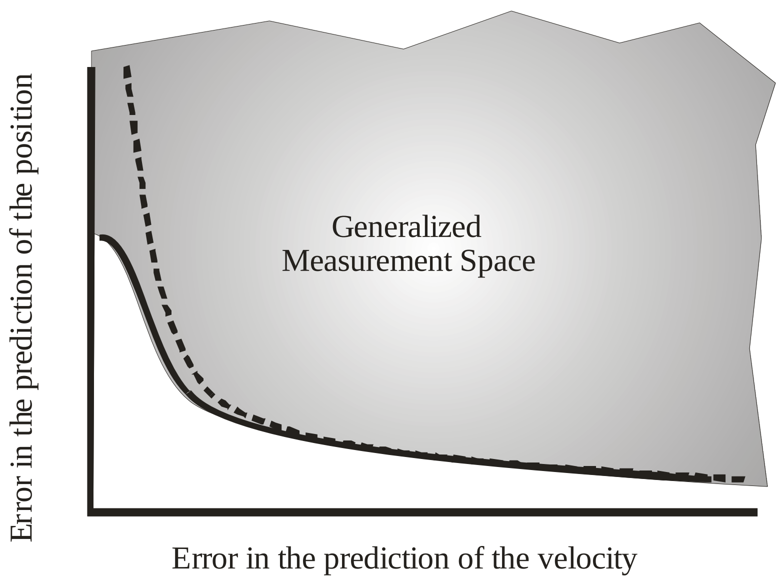


Fig. J7.7 – Abstract space of measurement accessible to non linear quantum physics, for a certain base wavelet.

In this case, as the basic element are finite waves, we can have an error in the prediction of velocity equalling zero, while the error in the determination of position is finite and given precisely by the dimension of the wavelet, as one can see in this drawing – and he showed Fig. J7.3. again. As you can see, from the formal point of view it is precisely here that the difference between both relations lie. The finite dimension of the basic mother wavelet defines, in this case, the minimum error in the prediction of the position.

As the dimension of this basic wavelet decreases, the inaccessible space of measurement grows smaller until in the limit all measurement space becomes accessible – and he draws Fig. J7.8:

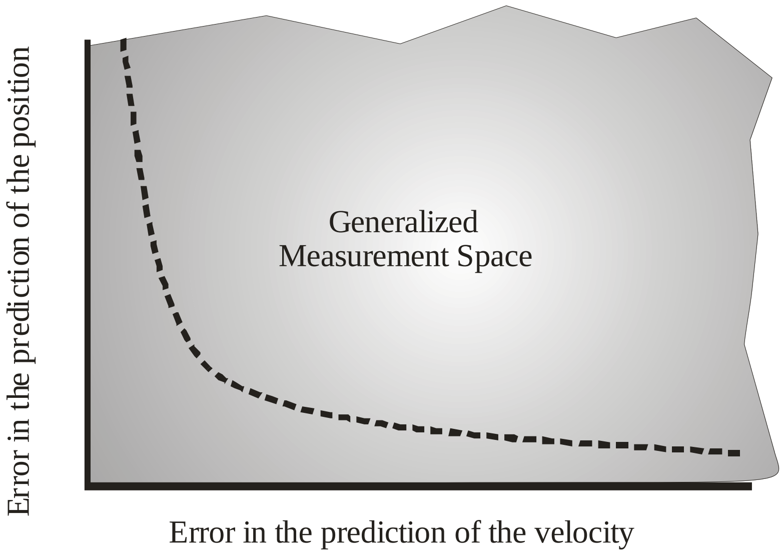


Fig. J7. 8 – Total space of the measurement accessible to nonlinear quantum physics.

In the usual relations the only wave that has a well defined frequency and consequently a velocity known with absolute precision is the infinite harmonic wave. In these conditions, it then follows that the error in the prediction of the position is infinite, because such is the dimension of that wave.

In new relations, as we have highlighted several times, we assume that as a starting point there can be finite waves, the Morlet waves for example, with a well defined frequency. We would then have a velocity known with absolute precision, while the prediction for error in the position is finite and given precisely by the dimension of that wavelet.

When the dimension of that wavelet grows until it reaches enormous values, the prediction for the error in the position comes close to infinite, for all practical effects, and we then have predictions similar in every way to the ones given by the orthodox theory. In fact, as you can see, the general relations of uncertainty contain all possible space, the Heisenberg-Bohr space plus the region considered inaccessible by the Heisenberg-Bohr relations. It is to be noted that, for comparison effects, I have always represented in the drawings, in dashed line, the line that defines the border of the accessible measurement space according to the orthodox theory.

I want to take up this opportunity to bring to your attention another very interesting fact. This new causal approach to the problem, apart from being a lot more general, also allows the usual concept of measurement to be recovered. Until the advent of quantum indeterminism, introduced in physics by the Copenhagen school, the measurement process was essentially limited by the tools used, since the error of such a measurement depends on the sensor used. If, for example, we want to measure the length of a table and for that we use a ruler graduated in centimetres, then surely the error in the measurement determination in the order of the centimetre. If, on the contrary, the ruler is graduated in millimetres then our error will be in the order of millimetres. No one, with good sense, would want to assess the dimension of a cell by means of a ruler graduated in decimetres, centimetres or even millimetres. In the same way, if we intend to measure within the field of electronics, for example, a difference of potential between two points of a circuit, we have to guarantee, in the first place, that our measurement instrument does not disturb significantly the system to be measured. If that happens, the result obtained by the measurement device will not have any meaning. Basically, it is a scale problem described in a quite adequate way by the local analysis by wavelets. According to the scale, temporal or spatial, that is the dimension of the base wavelet.

- So, I understood it – interrupted Lucius – with these wavelets we can simulate a measurement process in a method very similar to the real method. By using measurement devices in which the scale is very big, which is what happens in astronomical measurements, the base wavelet will naturally have to be the same size. If, on the contrary, we consider the measurements to the quantum scale, then the wavelet will surely be of that size.

- Precisely! You understood the great advantage of this important mathematical tool that is the local analysis by wavelets – exclaimed Argus, continuing:

- After this introduction, maybe somewhat lengthy, but in my view, necessary, we are able to study a whole family of concrete measurements, made every day, in several laboratories all over the world, that are not described by the usual Heisenberg-Bohr relations. We are talking about measurements made precisely in the region forbidden by these relations.

I want to mention again that the applicability or non applicability of Heisenberg-Bohr relations to real experiences is very important, since these expressions constitute the basic support of all orthodox quantum mechanics. On the other hand, since the interpretation of Copenhagen is accepted by the vast majority of the scientific community without, it must be stated, really understanding it, the problem of the validity limits regarding the orthodox relations assumes a fundamental importance. The affirmation that the venerated Heisenberg-Bohr relations can be violated is sufficient to give rise to a feeling of franc opposition amongst people, above all in the more conservative people. However, the word violation on its own is not sufficient to describe what is really at stake. No one affirms that classic mechanics is violated by the fact that there are physical phenomena not described by it. In the region of great velocities, that is, velocities near the speed of light, classical mechanics does not describe the observed phenomena, making it necessary to use relativity. In the same way, also on the quantum scale it reveals itself as insufficient, making it necessary to use quantum mechanics. This is because the theory, being developed in a certain experimental and conceptual context, has necessarily limits to its validity like any other human construction. The fundamental base of the orthodox interpretation of quantum mechanics resides in Bohr's principle of complementarity that, in its turn, finds its mathematical transcription in Fourier ontology, leading directly to Heisenberg-Bohr relations. The great problem lies in the conviction that in that theory our limitations in rationally understanding the world are exposed, once and for all. Such a position is equivalent to affirming that this theory is a limit theory, not being then possible to build a better theory than that one. I recognize, once again, that this theory is the best that man managed to build until today. It is a theory with enormous consistency and enormous ability to describe phenomena in the dominion of microphysics. But it is not THE THEORY in the sense that I have already talked about. For the simple reason that no theory built by man can be it!

Lucius decided to ask, trying to make a point of the situation:

- Are you telling us that what is happening with the Heisenberg-Bohr relations is a consequence of our experimental universe, on one hand, and on the other of the development of new conceptual tools having changed deeply? Since the old times of 1927, when these relations were created, this development would be such that now they are only able to describe a small amount of the microphysical reality? In these conditions, and taking simply into account that such relations are a simple human construction, necessarily resulting, as I said, from a certain historical context, we would have to conclude that, sooner or later, they will reveal their weaknesses and thus their application limits?

- I wouldn't be able to say it better than you, Lucius. Your questions already have your answers – said Argus, continuing:

- We are in a situation that did not happen many times in the history of physics. The real issue here is a change in paradigm. The inability already revealed by the orthodox indeterministic relations to describe, as we will see, a set of quantum phenomena showing that the Copenhagen paradigm has already reached its validity limits. It is not about, as I mentioned a simple and local violation of the established paradigm that eventually may be overcome with some "touches" to the theory, but a real change in the way of understanding things. In truth, it is about the passage of an indeterministic paradigm of idealistic roots to a causal paradigm that starts from a realistic position.

In order to present a clear and solid demonstration of orthodox relations' real limitations, so that everyone acting in good faith can understand it, I will analyse the paradigmatic example usually designated by the Heisenberg microscope experiment.

This conceptual experiment will be done simultaneously with two microscopes: the first is Fourier microscope, the only one known in Heisenberg's time and the second one is the optical super-microscope of the new generation developed by Pohl and his group.

The experiment of the Heisenberg microscope, that can be considered classic, has the advantage that it is talked about and discussed in great detail in most quantum mechanics texbooks. In essence, the experiment consists of placing a microscopic particle in the microscope observation area. A quantum of light will fall on this microscopic particle, a photon, transferring to it a certain amount of energy. After the collision the photon will be diffused and will eventually be captured by the microscope. After adequate treatment of the received information a luminous point that represents the position of the particle appears on the microscope visualisations' device.

- I did not understand very well what you said. Are you able to clarify the subject a bit better please – asked Amadeus.

- With pleasure – continued Argus:

- The best thing is to draw an image that is worth a thousand words – and he started to draw:

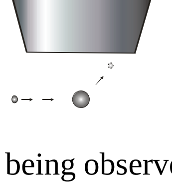


Fig. J7.9 – The micro-particle being observed is illuminated by a photon.

Since the M micro-particle that we want to observe has no light of its own, it will have to be illuminated. For conceptual simplification reasons, let us admit that this luminous source, not represented in the drawing emits one sole photon. This photon will hit, that is, will interact with the micro-particle, transferring to it a certain amount of energy. As is to be expected, after this interaction, the M micro-particle that was initially resting, will acquire a certain velocity, whose magnitude is also unknown. After this interaction the photon will be diffused and will eventually be captured by the microscope. As you can see in the image, if the photon is not captured by the microscope, nothing can be concluded. We will then have a measurement with a null result, that is, inconclusive.

It is an extremely simple method. The light coming from a source will illuminate the particle M, and will then be diffused. This diffused light will go into the microscope, where, after adequate treatment, it gives rise to the appearance of an image of the M particle. In this simple case, this representation is nothing more than a small dot, a region more or less extensive, where the image of the particle is located. In this case and to minimise the interaction of light with the M particle, this light was reduced to its more simple expression, to a simple quantum of light, that is, one single photon.

Our problem consists in predicting, before the concrete measurement is made, the uncertainty in the velocity of the microscopic M particle due to the inevitable interaction of a quantum of light with it, calculating simultaneously the error, that is, the uncertainty regarding the determination of the particle position.

Let us start with the prediction of the maximum uncertainty in the velocity of the M particle after the interaction with the quantum of light. The prediction of this error can be done in different ways. To see it, all you have to do is to consult different textbooks of quantum mechanics. Each author, who studies the Heisenberg microscope, aims to present a treatment as original as possible, as it would be expected. For that to happen, he presents calculations taking into account more or less parameters, weighing the different effects generalizing where possible, but at the end they all arrive at the same final result no matter how complex the path followed was.

This is a direct consequence of the starting assumptions of these authors. The purpose of all of them ultimately consists on deriving the mathematical expression of the Heisenberg-Bohr relations. In an ultimate analysis, these relations require from a formal point of view that the product of the position uncertainty by the velocity uncertainty must be superior or equal to the Planck constant divided by the mass. Then, as from the start the uncertainty in the position determination of a common Fourier microscope is determined and since, as we know, it is half of the wave length of the light used, there is in fact no freedom for the expression of the velocity uncertainty. Its value has to be such that its product by the uncertainty in the position is the same, in the ideal case, and in general superior than the Planck constant divided by the mass. As such – and Argus starts to write the formulas on a paper – if the uncertainty in the prediction of a particle position made by a Fourier microscope is given by

$$\Delta x = \frac{\lambda}{2}$$

where the Greek letter λ represents the wave length of the light; knowing that the mathematical expression for the Heisenberg-Bohr relations is

$$\Delta x \Delta v = \frac{h}{m}$$

one immediately concludes that

$$\Delta v = \frac{h/m}{\Delta x}, \quad \Delta v = \frac{h/m}{\lambda/2}$$

or simply

$$\Delta v = 2\frac{h}{m\lambda}$$

This result can and should be considered a good result, since it is confirmed in all experiments that use common Fourier microscopes. As I have mentioned, several authors always arrive at this last expression in their prediction for the error regarding the determination of a micro-particle velocity, illuminated with a light quantum, after a more or less hard process. In these conditions, the product of this uncertainty by the error in the position leads to the expected formula – and it points to the expression

However, this expression is related with the ideal case in which equality can be observed. In general we should write

$$\Delta x \Delta v \geq \frac{h}{m}$$

that is, where equality is, substitute it with the sign equal or greater than.

The quantum measurements are, in the case of Fourier microscope, made in these conditions and, as such, are made in the measurement space of Heisenberg-Bohr – in Fig. J7.10 he drew a point in the measurement space of Heisenberg-Bohr with the respective coordinates.

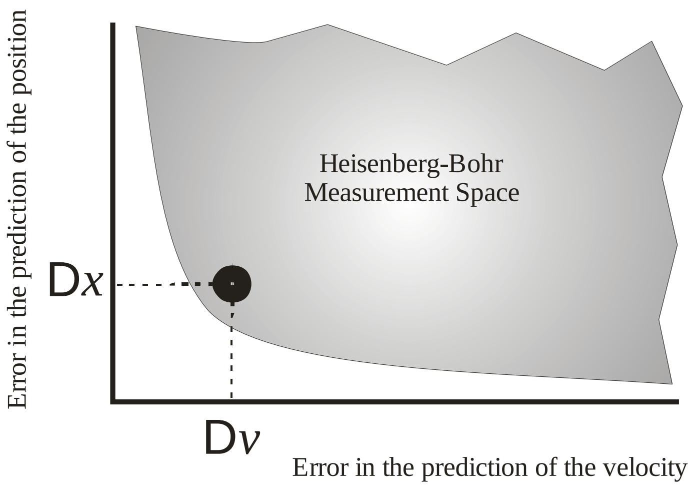


Fig. J7. 10 – Measurement made in the Heisenberg-Bohr space

- Let us now see – he continues – what happens if instead of using a common Fourier microscope we use an optical super-resolution microscope, the Pohl microscope, for example.

Regarding the determination of the velocity error it is all very similar to what happens in a normal microscope. This is simply because the phenomenon is identical. A quantum of light illuminates the micro-particle that is being observed. So, the uncertainty in the determination of the particle velocity is precisely the same in both cases, that is,

$$\Delta v = 2\frac{h}{m\lambda}$$

Regarding the determination of the position error we see that the photon is diffused after the interaction with the micro-particle and is eventually captured by the microscope. The uncertainty in the location determination comes naturally from the error in the determination of the position of the micro-particle. For super-resolution microscopes there isn't, or up until now there hasn't been discovered a limit of theoretical resolution derived from the first principles; all we have is its practical resolution. For the Pohl microscope we saw that one can get resolutions in the order of

$$\Delta x = \frac{\lambda}{50},$$

or even better. In these conditions the product of these two quantities amounts results in

$$\Delta x \Delta v = \frac{1}{25}\frac{h}{m}.$$

In this case, since we are using the practical resolution of the super-microscope, we do not need to substitute the equals sign by the superior than or equal to sign, like we did before. To make any change would be precisely the contrary, that is, substitute the equal sign by the smaller than or equal to sign

$$\Delta x \Delta v = \frac{1}{25}\frac{h}{m}.$$

This for the simple reason that in the demonstration we use a super-resolution microscope of low practical resolution. We know that we can really reach practical resolutions that are quite higher. This measurement, as you can see, was made precisely in the region forbidden by the usual relations. As you can see in the drawing – and he showed Fig. J7.8, where he makes a point:

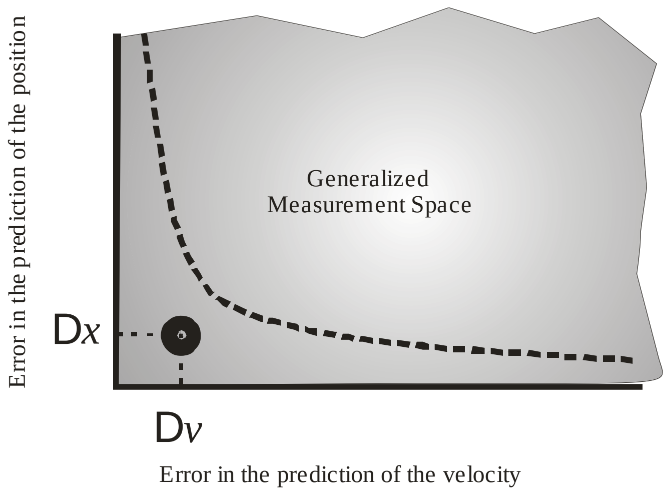


Fig. J7. 11 – Measurement made in the general space, that is, in the region forbidden by the usual relations.

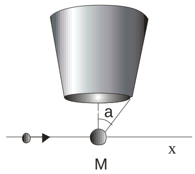
By the way, and to better help visualise and understand the whole process, I will show you a drawing that I did a while ago and that contains a summary of what I have said, that is, the evidence of limits regarding the Heisenberg-Bohr relations – and he shows Fig. J7. 12 (on the next page).

Proof of the limits of validity of Heisenberg-Bohr Relations

Measurement of Velocity and Position of a Partícle

PREDICTIONS

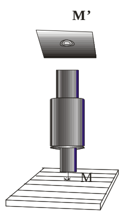
Incertainty (error) of Velocity



$$\Delta\upsilon = \frac{2}{m\lambda} h$$

Incertaity (error) in Position

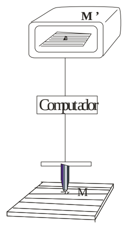
Common Fourier Microscope



Maximal Theoretical Resolution

$$\Delta x = \frac{\lambda}{2}$$

Super-microscope



Practical Resolution

$$\Delta x = \frac{\lambda}{50}$$

Uncertainties Product

$$\Delta x\, \Delta\upsilon = \frac{h}{m}$$

$$\Delta x\, \Delta\upsilon = \frac{1}{25} \times \frac{h}{m}$$

Fig. J7.12 – Evidence of the validity limits regarding the Heisenberg-Bohr relations.

As you can see, we obtained a discrepancy with the prediction of the orthodox theory of 1/25. It is best to keep in mind that this result was obtained, as I have already mentioned, using a super-microscope of low resolution; with those ones of higher resolution there would be higher discordances. This way, these results clearly show that the Heisenberg-Bohr relations do not describe the functioning of the optical super-microscope. It was then been proven that in truth the orthodox relations have limits to their application in concrete physical situations. In other words, there is a whole experimental universe not described by them. This Universe is perfectly described by the more general uncertainty relations.

- Ho Argus! – interrupted Lucius – When you spoke about microscopes, the Fourier one or the super-microscope, you did not mention the images obtained with a simple photon. Now, for the falsification of the indeterminism relations you spoke about a single photon. How does this all fit in?

- You are completely right! – exclaimed Argus – As always, you asked the relevant question.

In practice, as we know, in a normal working order both the common microscope or Fourier microscope and the super-microscope work with a great number of photons. There are good reasons for this. On one hand, it is very hard to make mono-photonic sources; that is, sources that emit with good reliability conditions one photon at a time. At first sight you could think that it was a easy task. For that it would be enough simply to reduce the intensity of a luminous source so that we had one simple photon in the limit. In truth, things do not happen that simply. It can be seen that photons have a special tendency to agglomerate. This tendency for photons to agglomerate, is called bosonic, or bunching effect. To break this tendency it is necessary to create special devices that only in the eighties of the last century were possible to make. Another very important factor is related to the impossibility to build detectors with an efficiency of one hundred per cent. That is, sensors capable of detecting all photons which reach them. Apart from everything, there are no theoretical reasons that prevent the common Fourier microscopes or the super-microscopes from working in a mono-photonic regime.

Aiming to clarify this subject a little better let us see how the optical super-microscope in mono-photonic regime can work in principle. For that let us admit for conceptual consistency reasons that our source emits one sole photon that hits the micro-particle whose position we intend to determine. On the other hand, we also assume that the detector has an efficiency of one hundred per cent and also that during the experiment there is no other parasite diffused light, or any other experimental difficulty that can forge measurement. In other words, we assume that we are working in ideal experimental conditions. Naturally, we are conscious that such ideal conditions are impossible to reach in any real concrete experiment.

Under these conditions, the simplified conceptual experiment unrolls in the following manner:

The single photon, emitted by the source, stikes the micro-particle, transferring a certain quantity of unknown energy into it. After this interaction with the micro-particle the photon is diffused and goes into the optical sensor that happens to be precisely located on the cone of detection. Once the photon has been collected, this sensor generates an electric impulse that goes into the computer. After that, the computer, the computer system, knowing the position of the light sensor, produces a pixel of non null intensity on the visualisation screen. The position of this pixel corresponds, at the observation scale, to the position of the micro-particle. The dimension of this pixel depends on the global resolution of the device. This dimension stands evidently for our error in the determination of the micro-particle position. In all the remaining areas of the monitor, constituting the background, you can see pixels of null intensity.

If the photon emitted by the source does not reach the micro-particle, no photon is diffused and as such no measurement is made. On the other hand, if the luminous sensor is not positioned on the diffusion cone, the photon is not captured by the sensor. So, no electric impulse is produced and sent to the computer and therefore no pixel with intensity different from zero is placed on the screen. Under these conditions, no measurement is made, which goes against our initial hypothesises that we were working in ideal conditions.

In conclusion, the measurement is only made if all the necessary conditions are fulfilled. These demands lead to the natural situation that many unfruitful attempts have to be made until a measurement is effectively achieved. In practice, this situation is overcome using sources that emit a lot of photons. In this case, and in first approximation, everything happens as if we were simultaneously making thousands of similar experiments. One of these experiments, fulfilling all the necessary requirements, lead to a concrete measurement eventually.

- I think I now understand what you meant – affirmed Lucius.

- Great – exclaimed Argus, continuing:

- As you can see, the functioning of the common microscope shows an interesting dual behaviour. It was precisely because of this that Niels Bohr saw the paradigmatic example of validity of his Complementarity Principle in the conceptual experiment of the Fourier microscope. The experiment made with the Fourier microscope proves the wave-corpuscle dualism in a particularly clear manner.

In first place, when the incident photon interacts with the micro-particle, transferring a certain undetermined quantity of energy into it and being diffused afterwards, it shows its corpuscular character. In second place, the photon, after being diffused goes into the microscope through the different lenses of the device until it gives rise to an image point on the screen. This image dot, distributed according to a diffraction spot, represents the position of the object. In this process the photon behaves like a wave entity.

In summary, in this experiment the photon sometimes behaves like a corpuscle and other times behaves like a wave. It is then no surprise the fact that it is really a paradigmatic experiment of wave-corpuscle dualism. Moreover, this experiment emphasises particularly well the fact that orthodox relations of indeterminism are nothing more than a simple mathematical consequence of the complementary principle.

The situation is completely different when the same experiment is made with a super-microscope. In this case, during the whole measurement process, the photon always behaves like a corpuscle; the wavelike aspect does not come into it. When it interacts with the micro-particle and it diffuses, the photon behaves like a corpuscle just like in the case of the common microscope. In the same way, when it is detected by the optical sensor where it produces an electrical impulse it behaves like a corpuscle. In these conditions and since during the whole measurement operation only the corpuscular aspect of the quantum being manifests itself, it is of no surprise that the complementarity principle has no relevance. The obvious conclusion to be taken is that the orthodox relations do not apply to this type of measurement entirely unknown in the time of Niels Bohr.

Due to the late hour we will interrupt our discussion being careful, however, to set the date of our next and last discussion.

EIGHTH JOURNEY

This time, I was the first one to arrive at the Bookshop of Eternal Return. I sat down at the table, ordered a beer and began to consult the annotations I had made of the previous journey, while waiting for the other discussion group members to appear. The conclusion I had made, and which I reinforced while reviewing notes from the previous Dialogues, was the insurmountable fact that, already in the 21st century, some people not only accept but even very strongly defend, a non realistic view of quantum physics. To me, this situation seemed unusual and unexplainable, since as we had verified, and Argus had shown, it was possible to understand all quantum physics in intuitive and causal terms. It was as if there were occult forces working to promote irrationalism, to prevent the progress of knowledge and, consequently, to stop the evolution of the human thought.

I was lost in these considerations when Lucius and Amadeus arrived and warmly greeted me; after sitting at my table they ordered coffee, we started talking, naturally, about quantum physics.

Lucius was quite satisfied with our last dialogue, where, not only had we seen clearly that there was an extremely solid alternative to anti-realism, but had also verified that the anti-realistic orthodox theory did not have, as expected, the ability to explain all experimental evidence, not even at a quantum level.

Amadeus was a bit disappointed and Lucius, who truly cherished him, mostly due to his generous and honest character, tried to make him understand that this new situation did not oppose individual religions, the belief in the idea of a God. Naturally, this is a God that is not described in any book written by men, books such as those become a Dogma. If God exists, the only book in which we can find Him is in the book of Nature.

Lucius, like me and Argus, was agnostic, but respected those who believe in the idea of a God. Moreover, a God who he strongly believed taught us to love ourselves. Next, Lucius underlined that, in his opinion, religious and faith are one thing, science is another, completely different: the best that can happen to both is not to get mixed up. Each one has its very particular field of action.

This position cannot be considered the defence of the doctrine of the double truth, a flag that served the human thought in order for it to liberate itself from dogmas and dogmatisms. I believe that searching for the truth is the ultimate purpose of science. A truth which I relate to the deep meaning of the book of Nature, like Argus had told us a few journeys ago. But this is a quest that must be, above all, humbly undertaken. Humble as in knowing that no one owns the truth. An attitude in complete contradiction with that of those who believe that the truth is contained in one or several books that mankind has written and rewritten throughout the three and a half millenniums of monotheistic beliefs. No belief should attempt to control the advances of science. It suffices to remember, among others, the sad stories of Giordano Bruno and Galileo, not to mention the more recent project of a theory that is Darwin’s origin of species. Whenever religion had got itself involved in scientific disputes, aiming to control the investigation, sooner or later, they came to regret it. Science, precisely because it is science, can never support dogmas. No belief can expect their “truths” to be confirmed by science. This is a naïve attitude, but also a very dangerous one.

Meanwhile, Argus and Fabrus arrived, sat at our table and ordered an excellent tea that was served at the Café. After the usual greetings and information exchange, we resumed our dialogue. Argus took the word:

- In the previous journey I have shown the limitations of the anti-realist orthodox theory; today I will speak of a whole series of situations that can originate concrete experiments to reinforce the need for a change in the quantum paradigm. I will start by referencing a device, a very simple one from a conceptual point of view: the photonic condenser.

The photonic condenser, or light condenser, is a device which, like the name implies, is able to passively accumulate or store, during a certain period of time, a determined amount of photons. In reality, this is a device similar to a common electrical condenser, only instead of accumulating electrons it accumulates photons. The electrical condenser was discovered in the 18^{th} century in a city of Flanders called Leyden, hence the first devices where called Leyden bottles. Since we are at it, I would like to mention that a first experimental version of the photonic condenser was made in 2001-2002 in the Physics Department of the Faculty of Science at the Lisbon University.

There are, in principle, many ways of making such a device. For example, a crystal made in such a way to allow a beam of light to penetrate it and to be successively reflected, by total reflection, in a way that it describes a trajectory with a tendency to close, or even an optical fibre, with a function similar to what is described by the following scheme:

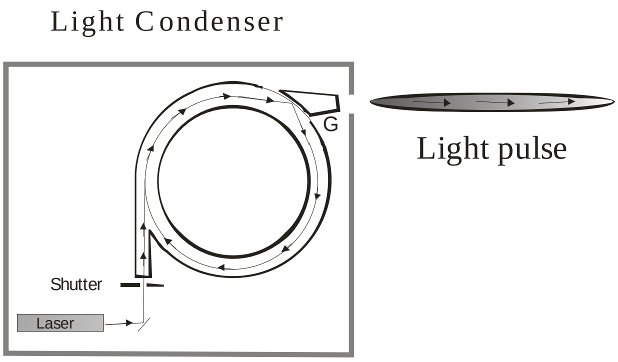


Fig. J8.1 — Light condenser.

This device has the ability to continuously accumulate the beam of light penetrating it in order to increase its intensity thousands of times. At first sight, we could think that such an increase in the beam of light's intensity within the ring would be infinite. Obviously, it is not so, because from a certain value of maximum luminous intensity the system no longer behaves linearly. From this limit on it starts to lose light, reaching a regime of stationary intensity. The device also has a window the accumulated beam can use to exit.

Once the global functioning of the condenser is understood, let us consider the following experiment:

The condenser is loaded until it reaches the stationary regime. Next, the shutter which is placed at the exit of the laser light source is closed. Then, the window is opened, allowing for the accumulated light, in the form of an impulse, to exit, as we can see from the drawing.

The question that now arises is to know if Heisenberg-Bohr relations are capable of describing the behaviour of the light condenser.

The orthodox relations applied to this situation tell us that the light impulse exiting the condenser must be such that, under any circumstance, one always verifies the condition under which the product of uncertainty of its frequency, its colour, by the uncertainty of impulse time period, is always equal to or greater than Planck's constant, that is – and he wrote the following formula:

$$\Delta \nu \, \Delta t \geq h$$

That means the uncertainty of the light's colour, that is to say its frequencies' bandwidth, or the light's colour range, to be multiplied by the duration of the light impulse exiting the condenser must always be equal to or greater than Planck's constant. This result, as you can see, is no more than a simple consequence of Fourier ontology. The shorter the impulse is in time, the more infinite harmonic waves we have to find to reconstruct it. Symmetrically, the greater the impulse's duration is, the less harmonic waves will be needed to reconstruct it. At the limit, when the impulse's duration is infinite we are left with a single harmonic wave with a well defined frequency. In this extreme case, the frequency uncertainty is zero, that is to say, we have an absolutely pure colour, while the uncertainty in the impulse's duration is infinite.

Let us now see if such relations are generally valid, namely, if they are applicable to the very concrete case of our photonic condenser.

Firstly, we start by determining the uncertainty or the dispersion variation, that is, to determine the colour bandwidth of the light impulse exiting the condenser. Since the device works in a linear regime and since we are always working on low intensities, one expects that the colour of the light exiting the ring is the same as the laser source that feeds it. In other words, if the light entering the ring is red, the light exiting the ring must also necessarily be red. Equally, if the colour of the light feeding the condenser is green, the exit impulse will also be green.

Let us now see what happens with the impulse's duration. On what factors do you think the light impulse's duration depend on when exiting the condenser? – he asks, facing Lucius.

- If I understood the principle of the light condenser correctly – Lucius replied -, it seems to me that the duration of the impulse depends fundamentally on two conditions:

a) The device's geometry, I mean, the dimensions of the light ring;
b) The process used to extract light from the condenser.

- Exactly! – Argus agreed. – You have just called our attention to the fact that the impulse's duration is an entirely independent variable regarding the nature of the light source that feeds the accumulation ring.

Now, if the independency between the colour bandwidth of the light impulse and its duration is valid, we have a real contradiction with the predictions of Fourier ontology, and, therefore, with the orthodox indeterminist theory.

Fourier ontology establishes, as we have seen several times, that there is always, in such cases, a mandatory interdependence between the uncertainty on the frequency and the uncertainty in time duration. The uncertainty in colour and the impulse duration are, in this case, Fourier's dual entities.

However, if there is independency, in principle, nothing prevents us from choosing a source of laser light that is able to issue a very pure colour, that is to say, with an extremely narrow frequency bandwidth, and simultaneously design a relatively small condenser in a way that the exit impulse's duration is short. In such conditions, and since we are dealing with completely independent variables, we can perfectly have: - and he rewrote the previous formula where he only changed the "greater than or equal” symbol to “very much less than” Planck’s constant.

$\Delta\nu\, \Delta t <<< h$

As we can see, we are clearly in contradiction with Fourier ontology. This experiment is one more case that points out the applicability limits of the orthodox anti-realistic quantum mechanics.

- Of all that has been said it seems to me there is no doubt left about the real limitations of the orthodox theory. Thus, it is necessary to replace it with a more general theory – Lucius remarked.

- That theory, as I have shown you, already exists – added Argus. – I would like to mention a rather interesting consequence of the causal realistic theory which derives from the very nature of the quantum particle. This, as we know, is formed by the corpuscle, the acron, and its guiding wave. In spite of being intimately correlated each of these entities have a distinct specific behaviour.

Let us then see what the behaviour of the guiding wave is, or theta wave, as it is better known.

From the interferometry experiments with a single particle we verify that there are concrete situations where it is possible to isolate theta waves. Namely, in the two slits’ experiment. In other words, it is possible to conceive a way of obtaining theta waves deprived of a corpuscle. This theta wave, like any other physical wave, like for example a common electromagnetic wave, can be reflected, diffracted, and so on. Let us consider a situation where this guiding wave impinges on a 50% semi-mirrored mirror, meaning that half the incident wave is reflected, while the other half is transmitted. If, in the course of this transmitted wave, we place another similar mirror, the same will occur. That means half the intensity of this wave is transmitted, that is, a quarter of the initial theta wave. The experiment can be repeated by placing similar mirrors in front of the transmitted beam, as shown here:

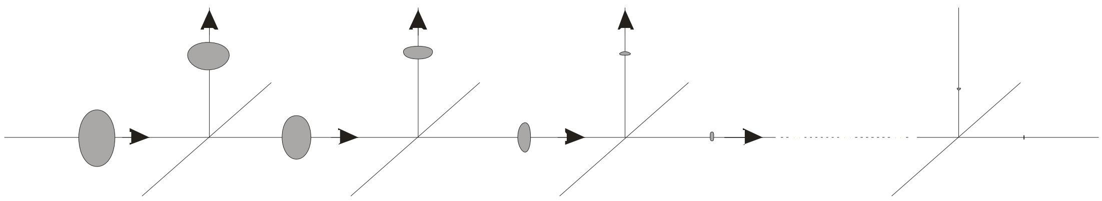


Fig. J8.2 – While crossing successive semi-mirrored mirrors the theta wave progressively loses intensity.

As we can see, being that a theta wave is a real physical wave, when divided by several semi-mirrors it progressively loses intensity until it eventually completely disappears.

As for the complete wave, wave plus acron, or the quantum particle’s behaviour, things are somewhat different.

Let us suppose we repeat the previous experiment, only this time instead of using theta waves we use quantum particles, that is to say, the complete entity formed by the acron and its guiding wave. What can we expect from this experiment?

We know that, in virtue of its indivisible nature, the acron is either reflected or transmitted. Thus, after the interaction with the semi-mirrored mirror, the acron is either reflected or transmitted while the theta wave is simultaneously reflected and transmitted. For obvious reasons, we will only consider the situation where the acron is transmitted. The cases in which the acron is reflected are set aside because these do not lead to any detection, since it is made only for the particles which will always be transmitted in every semi-mirrored mirror. The associated guiding wave's amplitude, in each transition or each interaction with the semi-mirror, is reduced to half. If this process of amplitude reduction were to continue, we would reach such a point that the theta wave would be so tiny and we would have, in practise, only a completely isolated acron. We would have an acron without its associated guiding wave. This would be a situation where there would be a quantum entity with no associated wavelike characteristic. In summary, it would be a purely corpuscular quantum entity. In this case, Louis de Broglie's basic hypothesis, fundamental to all quantum physics, which states that to each corpuscle, or acron, there is always an associated guiding wave, would be broken.

To avoid the collapse of all quantum physics we will have to admit that there is a more subtle interaction between the acron and its wave. It is reasonable to assume that, after reaching a minimum energy, compatible with the aforementioned basic hypothesis, the process of amplitude reduction of the theta wave ends. To this point on, the theta wave's amplitude remains constant, to all practical effects. This situation of a theta wave's minimum energy corresponds to its fundamental state. If the guiding wave's energy from this point on remains constant, in average, we need to compensate for the lost energy in each transition. This energetic compensation can only come from the acron associated to it. Thus, in each transition, that is to say, in each interaction with the semi-mirror, the acron loses a minute amount of energy in favour of the guiding wave. This scheme – and he draws Fig. J8.3 – tries to illustrate this situation.

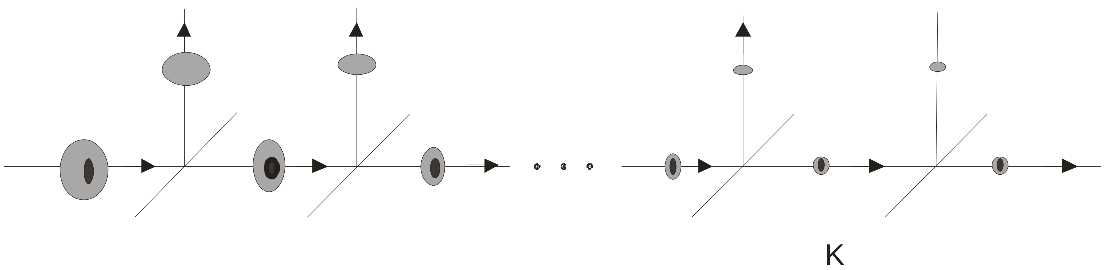


Fig. J8.3 – Quantum particle's interaction process.

The whole interaction process of the quantum particle is thus divided into two parts:

a) In the first part, the acron maintains its constant energy, while the guiding wave's energy diminishes continuously until it reaches its fundamental state;

b) In the second part, from a certain point k on, the acron begins to lose energy providing it to the guiding wave, so that the latter maintains its fundamental state.

This means that while the quantum particle crosses the successive semi-mirrors it gradually loses energy. You must note that I have said the particle's energy and not the acron's energy. This happens for the well known reason that to all practical effects the particle's energy is the same as the acrons's energy. In fact, we know that the acron's energy is incomparably greater than its guiding wave, billions of billions of billions of times superior.

As long as we are at it, I would also like to add that this interaction model of the quantum particle can be perfectly tested in a laboratory. However, since this experiment's explanation involves some mathematics and is published in scientific literature, such matter will not be discussed here.

I must remark that the previously described interaction process can be conceived, either with 50% transmission capacity mirrors, or with 99%, or any other value. The process is, in principle, independent from the concrete value of the transmission coefficient. Naturally, the greater the transmission coefficient is, the more interactions will be needed to obtain the same attenuation in the particle's energy. From what has been said, we can understand that a medium constituted by a large succession of semi-mirrors is, to all practical effects, equivalent to a continuous medium. In such a continuous medium, the quantum particle progressively loses energy as it crosses through it. In case this quantum particle is a photon, this energy loss is equivalent to say that it progressively changes colour. If the photon is issued by the source in a violet colour, as it crosses the medium, it turns blue, then green, yellow, red, etc. Thus, it is understood that a beam of light, which is, in fact, formed by a large number of photons, while travelling through sidereal space, interacts with the sub quantum medium which fills it and loses energy due to the mechanism I mentioned, walking naturally towards red.

The generic formula that gives the loss of energy the photon experiences while travelling through sidereal space is no more than an exponential decay, similar in type to the radioactive decay. Indeed, this formula was initially proposed in 1935 by Nernst. However, in order to achieve that mathematical expression, this physicist followed a totally different course from what has been mentioned. I remind you that radioactive decay is closely connected to the duration of nuclear residues. An equal formula was advanced by Finlay-Freundlich in 1953 and by Max Born in 1954. Later, in 1962, the idea of the so called ageing or decay of the photon was regained by Louis de Broglie, even though he has not developed any explicit photon interaction mechanism.

Even if the model of the photon subquantum interaction may be, as I have mentioned, tested in a laboratory, there are nonetheless clear indications of its validity. These indications occur within the cosmology domain. In fact, both Nernst and Broglie, together with some other ones, developed their models with this idea in mind.

At this point, our well-known Hilarius entered the Bookstore of Eternal Return. With his usual arrogance and boastfulness he immediately sat at our table.

- This is an interesting story - Argus proceeded -, and simultaneously illustrative of the strong influence of religious assumptions in the acceptance, even if temporary, of certain so called scientific ideas that become fashionable and are taken as dogmas, began more or less between 1910 and 1920. At the time, Vesto Shipher found out that the light that reaches us, coming from near galaxies, presents a systematic detour to red, which is known as *redshift* in scientific jargon. Due to the spectroscopic discoveries in the late 19th century one knew that chemical substances, formed by elements, issue a characteristic light, called a spectrum, when excited by electrical discharges or any other process. This characteristic light, or this spectrum, is related to the chemical composition of the substance in question. This spectrum, characteristic of each element or substance, constitutes, so to speak, its *signature*. One example may be easily observed when grains of kitchen salt fall on the stove's open flame. This flame changes colour and goes from its natural blue colour to a yellowish colour, due to the excitation of the sodium atoms contained in the salt. We know, from previous studies, that when sodium is excited it issues a very typical yellowish light. Thus, if a given substance, common salt for example, when excited issues a similar colour this means that the referred element is present in its chemical composition. By the way, the name of the physics branch dedicated to this type of study is spectroscopy. Spectroscopy is nowadays a powerful method for discovering the composition of substances.

It was thus verified that there was a persistent shift of the cosmic objects' spectrums towards red. That is to say, the lights from these objects' reach earth a bit "reddish". From the data of such observation, Hubble elaborated in 1929 a mathematical expression, which was named after him, relating to the cosmic objects' distance with this shift towards red. I must add that it is only an approximate expression. There is no need to mention that Hubble's expression is a particular case, the linear approximation of the general formula obtained from the model regarding the subquantum interaction of the quantum particle.

No one within the scientific community doubts this fact, this observational evidence. The problem that arose, and still does, is to know why the light emitted by distant astronomic objects is "reddish".

Several hypotheses have been put forth up until today to try to explain such an observational fact. Here, we only refer to the two most accepted explanations.

The first one was mainly due to Abbot Lemaitre. This man of the church, an ordained priest in 1923, interpreted that observational fact assuming as a fundamental premise that the photon, that strange entity that forms light, in its course of billions of billions of kilometres until reaching the Earth, maintains the same intrinsic frequency. In a common language this means that no matter how big the course of the photon through cosmic space may be, it remains unchanged, maintaining always the same frequency. Since frequency is proportional to energy, that means the energy that a photon holds at the start, when issued by the cosmic object, is precisely the same it holds when it reaches the Earth. And this, is even after it has travelled astronomic distances throughout sidereal space for billions of years.

In other words, this interpretation attributes the photon, that complex quantum particle, a completely different ontological status from any other natural system subject to a loss of energy, and therefore to a natural ageing process. Thus, if the photon always remains unchanged, with the same energy, the frequency does not vary no matter how long it has travelled in space.

Once the hypothesis establishing that the photon is perennial is accepted, in order to interpret the observed shift towards the red we have nothing left but to resort to Doppler's effect, characteristic of pure wave phenomena. This wave effect mathematized by Doppler in the 19th century, can be observed when a vehicle which is in motion and issues sound, like when a train for example, approaches us. We can verify that the sound issued becomes more acute as the train's velocity increases. When the train goes away, the reverse phenomenon occurs, the sound becomes less acute. That means the sound frequency measured by the observer at rest changes according to the velocity of the emitting source. In such conditions, in order to know if the wave emitting object is coming closer or going away, we only have to measure the frequency in which a known sound approaches us. If the source is coming closer, the frequency increases. When it goes away, it diminishes. This process, which we call Doppler's effect, is used by the traffic police to determine if a certain driver is driving at an excess speed or not.

Since light has wave properties, a similar phenomenon must also be observed with luminous sources. Thus, if light coming from astronomic objects presents a systematic shift towards the red, which corresponds to a reduction in frequency, this means those objects are moving away from the Earth. This explanation, as one can see, is based on the idea that light is a purely wave phenomenon, completely setting aside its inherent corpuscular nature, that is it quantum characteristics.

From such presumptions, the astronomer and priest Georges-Henri Lemaitre then claimed that the systematic detour towards the red, *redshift*, is evidence that the stellar objects are moving away from us, thus, the World, and the Universe, are expanding. Which implicates that if all bodies in the Universe are moving away, or expanding, there must have been a beginning. This is what originated the idea of the Big Bang, the Great Explosion. In the beginning, matter would be concentrated in one primordial “atom”, later exploding in a Great Bang, which would have originated the World.

The process of the Universe’s creation, instant by instant, with more or less detail, can be found in any scientific book related with cosmology. Thus, Abbot Lemaitre managed to conciliate his religious beliefs with the facts. He succeeded in harmonizing his religious beliefs with observational evidence.

For having achieved such a remarkable deed, to obtain an “agreement" between science and the Bible, he quickly became promoted up the religious hierarchy, soon becoming director of the Vatican Pontifical Academy of Science.

In a similar attitude that intended to justify religious truths resorting to science, in 1951 Pope Pius XII claimed that modern science, namely astronomy, had brought solid evidence of the intrinsic veracity of the Sacred Scriptures, the famous Big Bang was no more than an empiric evidence of the primordial “Fiat Lux” (Let there be light).

The alternative explanation for the same observed phenomenon, the shift of light coming from cosmic objects towards red, ultimately results in accepting that the photon has an ontological status similar to all other quantum entities.

Thus, the photon experiments, in its path throughout sidereal space, an interaction with the medium in which it travels, entering in a process of energy loss, or degradation, in other words, it is subject to a natural ageing process. Just remark that such an explanation does not constitute an *ad hoc* hypothesis put forth to explain the result of astronomic observations! It is merely a consequence of the corpuscular quantum nature of light, therefore entirely integrated in the general picture of the modern nonlinear quantum physics.

At this point, Hilarius, who kept twitching while listening to Argus, exclaimed with his so characteristic rudeness:

- That all looks lovely, but the Big Bang theory, which has been overly proven, has in its in favour more than just the arguments resulting from the *redshift.* Luckily, and to end once and for all those speculative deliriums of a hypothetical photon ageing, there are further evidences that prove the reality of the Universe’s expansion. Among such evidences I am referring to the space temperature. This value has been calculated for the first time by Gamow. Based simply on the Universe’s expansion he managed to determine the space temperature about a decade before Penzias and Wilson experimentally discovered it.

The expansion of the Universe is clearly demonstrated in two ways:

a) The first one, from the *redshift*, which must be interpreted exclusively in terms of the Doppler’s effect.

b) The second one, deriving from determination, first theoretic and then experimental, of the space temperature as a simple consequence of that very expansion.

Everything else that might be said lacks scientific validity. This verification is more than proven by the enormous acceptance; I shall even say the universal acceptance of the Universe expansion. Indeed there are a few dissidents who, however, are but minorities defending obsolete thesis, like those sects that up until today, already in the 21st century, persist in claiming that the Earth is flat. The expansion of the Universe is a scientific irrefutable fact and everything else is delirious!

To such a blunt speech, Argus replied in a rather tranquil manner:

- It is true that the great majority of the scientific community accepts the expansion of the Universe. It is also correct that most scientific books only refer to the explanation of the shift towards red, completely silencing all other interpretative possibilities for the same phenomenon. Namely, admitting that accepting such hypothesis necessarily implicates attributing the photon a very special ontological status, a perennial status translated in its inalterable state while travelling through sidereal space for billions of years. In such conditions, it is not surprising that the general public, not knowing the true implications of such a model or the possible alternatives, gladly accepts the model of the Universe expansion as “scientifically proven”.

But, I now ask, when is it that a scientific truth is proven by voting? We know that the argument of a majority acceptance of a given model to confirm its validity has been used by the Aristotelians against Galileo. I answer to you in the same way as he did, by saying that the truth cannot be found by means of voting! It most certainly is not the number of people who believe a given scientific theory that proves its validity. If it were so, if the scientific truth could be established by the number of its supporters, Galileo, Giordano Bruno and all of us, today, would be in trouble, since the majority then defended the heliocentric model. At the time, almost everyone believed that the Earth, a small planet revolving around the Sun, which is no more than a simple star of our Galaxy, was the centre of the Universe. The progress in science came to show, as we all know, that the magic-religious dogma of the Earth as the centre of the Universe was fake. Contrarily to other human activities, the validity criterion for a scientific statement does not derive from a majority of supporters, in general not very enlightened, or from who speaks the loudest or the bluntest; it depends, ultimately, of its conformity relation towards the phenomena. Luckily, in science, the validity of an affirmation is not a matter of opinion, but the result of a complex process of validation, which is ultimately decided by resorting to experimentation.

Regarding the fact of the intergalactic space temperature being a consequence of a hypothetical expansion of the Universe, I must say the following:

This is, once more, and as we will have the opportunity to verify, a rough and tendentious manipulation of information, more characteristic of the political activities than of the scientific praxis, withdrawn from the essential mission of Science, which consists solely in the search for the truth, against all tides. It happens that the story of space temperature determination began in the late 19^{th} century, at the time resorting to recent developments of thermodynamics and statistical physics. From the empiric observations, in 1879, Stefan discovered the quantitative relation between the temperature of a body and the energy it emits. Since we know that luminous energy is proportional to frequency, we can conclude that an object's colour is related to its temperature. This fact is not at all surprising in itself, for we all know, especially those who have had the opportunity to observe a blacksmith at work, that when an iron is heated at the forge, it initially has a dark red colour, and as temperature rises red turns to intense ruby; later it evolves to yellow and, ultimately, to white. Thus, when we look at the stars we can estimate their temperature in an extremely simple way, from the colour of the light they emit. If the star has a red colour, then its temperature is relatively low. If it is yellow, as in the case of our Sun, then it has a medium temperature. When the star is bluish or even violet, its temperature is much bigger; this happens for the simple reason that Stefan’s law is not a simple linear expression. In fact, it establishes that frequency, or colour, of a luminous source is proportional to the fourth power of its absolute temperature (we must multiply the absolute temperature four times by itself). Based on this law and in statistical studies, Guilhaume established, in1896, that the temperature of space had a value between 5 and 6 absolute degrees. Here we must notice the clear disagreement with the official creationist’s current speech that attributes

Gamow the primacy of such a discovery. This is in perfect contradiction with the historical truth! Our first estimate of space temperature was made eight years before Gamow was even born, which happened in 1904! I must also add that this was a good estimate, since Penzias and Wilson, in 1964, experimentally determined that same temperature as 3.5 absolute degrees. Lastly, we must consider that there are certain indications which lead us to believe that this estimate of space temperature was not even the first one. Anyway, this story of space temperature determination based solely in thermodynamics and physical statistics, and more, completely ignoring the creationist hypothesis of the Big Bang, does not end here. I will refer only some authors of which I have solid information, starting with Eddington, who estimated this temperature at 3.18 absolute degrees in 1926; Regener, 2.8 absolute degrees; Nernst, 0.75 degrees in 1938; and Finlay-Freundlich, 1.9 degrees in 1952. Not until 1953, as we have seen, did Gamow, supported by the hypothesis of the Universe's expansion, estimate a value to the temperature of space at 7.0 absolute degrees. This late value, as we can see, does not even constitute a better result comparing to previous of Guilhaume, obtained half a century before. Quite the contrary!

As we can well see, the only conclusion that can be drawn from these facts is that space temperature is absolutely not a consequence of any creationist hypothesis of the Big Bang. In fact, as we have seen, this same temperature may be estimated from other far more reasonable hypotheses, which have nothing to do with creationism.

Another more general consideration I would like to make before closing this subject is the verification that whenever one intends to make a claim of an absolute nature within science, sooner or later, new experimental facts come to show that, at the very best, such assertions of a dogmatic nature are no more than simple approximations, mere descriptions gifted with greater or lesser predictive power, and nothing more.

The means we presently have, either in terms of conceptual tools, either in experimental and observational terms, are necessarily limited, in space and in time: the spatial information, given by the present observation data of microscopes and telescopes; and the temporal information, given by the duration of human culture, which does not reach, at the very best, a million years. Thus, how is it possible that from our tiny island in space and time, we dare, I shall even say we intend, to hold the scientific knowledge of the Universe in all of its development in space and time? From such little information, how is it possible to believe that such purpose, such absolute knowledge, can really be achieved?

Before the open fire of Argus argumentation, Hilarius did not know how to answer, and once again, dispirited, left the Bookstore of Eternal Return. Some uneasiness descended over our table, which was broken by Lucius, when he inquired of Argus:

- You had said you would tell us of a few ways of testing, unequivocally, the validity of the causal nonlinear theory against the orthodox anti-realistic theory. Have you finished?

- Far from it - Argus replied with a smile. – There is a wholly different domain of extremely fascinating experiments which allow us to test the validity of these two conflicting theories. Besides, this family of experiments has the substantial virtue of being "yes or no" experiments, at least from a conceptual point of view. This means that the result of the experiment, if it is performed according to the mandatory experimental requirements, is conclusive in one way or another. It either leads to the rejection of a theory or not. From these experiments I will mention those which aim to find out if the wave, solution for the quantum mechanics evolution equation, is a real wave; or if, on the contrary, it is a probability wave deprived of any physical meaning as claimed by the orthodox theory.

Before I proceed, I would like to call your attention to the fact that I have said “quantum mechanics”, without discriminating if it was linear orthodox quantum mechanics, or nonlinear causal quantum mechanics, to keep it simple. On the other hand, from a formal point of view, there is no disagreement, since the modern causal nonlinear theory holds, from a mathematical point of view, the orthodox theory as a limiting particular case.

To discover the nature of the wave solution for the evolution equation, means: to know if it is a real wave, or a probability wave, which is fundamental in order to decide on the validity of both conflicting theories.

The non real existence of the wave solution to the evolution equation is rooted in the very conceptual and intimate structure of orthodox quantum mechanics. This wave, this mathematical function, which according to the orthodox interpretation has all the information we could ever have on quantum phenomena, does not allow us to describe the evolution of a particle in the framework of space and time. This is why it is seen as a mere probability wave, thus forcing us to speak of potential states instead of speaking of the real states of a particle before measurement.

On the contrary, in causal nonlinear theory we start with the assumption that there is, indeed, an objective reality. If this is so, the mathematical function, the wave describing that entity is gifted with a real existence, and must be faced as a physical wave and not a merely probability wave.

At this point, Amadeus calls our attention to one fact:

- A while back, I do not remember exactly where, I saw a reference to an interpretation of quantum mechanics based on David Bohm. As it seemed, the authors presenting such an interpretation were very enthusiastic. On the other hand, we have also spoken of this author in previous dialogues. So, I would like, if possible, for you to say something about it, and as long as we are at it, if you could refer what the meaning of the wave’s function was in such a theory.

- As I have previously mentioned – replied Argus -, there is a theory, developed mainly by David Bohm, with a predictive ability entirely similar to that of the orthodox theory. Its supporters are rather satisfied with it, mostly because it has the supreme virtue of never conflicting with the predictions of the orthodox theory. In this case, its defenders are well protected! Predicting exactly the same as the orthodox theory, there is no danger of being refuted by the conventional experiments. When it comes to not so conventional experiments, like the ones I am about to mention, its predictions are precisely the same as those of the orthodox theory. This means that in "yes or no" experiments David Bohm’s theory is in equal circumstances to this one. If the experiment refutes the orthodox interpretation, it will also refute David Bohm’s interpretation.

I believe that, in a way, I have answered your previous question regarding the meaning Bohm’s theory attributes to the wave. Just like in the orthodox theory, in this quantum mechanics interpretation the wave function is nothing but a probabilistic mathematics deprived of any physical reality.

Since the new causal local and nonlinear theory does not hide behind smoke screens, we cannot settle for this indulgent attitude. So, we must make an effort and try to find experimental situations, liable to be executed, and which allow unequivocal deciding as to whether quantum waves are real, or if, on the contrary, as the indeterminist theory claims, are not but merely mathematical probabilistic entities without physical meaning.

To better understand the problem let us consider the following experiment:

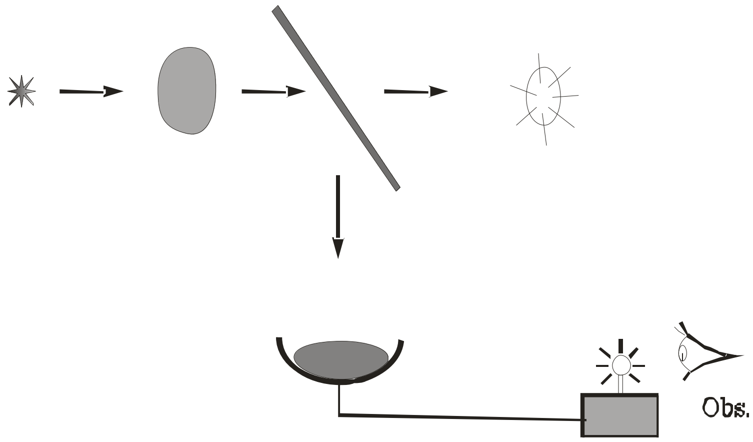


Fig. J8.4 — Nature of the wave function

In this drawing we have a source of quantum particles which, as usual, emits one particle at a time. One must ensure there is never more than one particle at a time in the experimental device. This particle, in its course, finds a semi-mirror where it has a 50% probability of being reflected and a 50% probability of being transmitted. Let us imagine that we place a detector along the reflection path. Such a detector may eventually be activated. In that case, it will send out a signal which turns on the light the observer is watching. In case the detector is not activated, the lamp will not light up.

Assuming that the observer watches the light turn on, can you tell me, Lucius, what happens along the transmission path? That is, if we assume, according to the orthodox theory, that the particle has a mere potential or probabilistic existence before the measurement?

- If I am not mistaken, the explanation for this experiment in the orthodox perspective is that when arriving at the semi-mirror the initial particle originates two potential particles, one being transmitted while the other is reflected. If the observer watches the light turn on, that means the particle has activated the detector. In such conditions, the probability of the particle being in the transmission path becomes null. If I have understood the experiment correctly, after the observer watches the light turn on, there is no trace of the particle in the transmission path.

- Exactly! You have perfectly understood the position of the orthodox theory. As long as we are it, what do you think the causal nonlinear theory has to say about this same experiment, Amadeus?

- Well – replied Amadeus -, I think that, in this case, the explanation will be a bit more complex. We have to bear in mind that one starts from the assumption that the particle really exists and moreover, that it is formed by that theta wave and also by the highly energetic acron.

Thus, the theta wave, being an extensive entity, is partially reflected and partially transmitted. The acron, the only entity of the particle able to activate the detector, being indivisible, is either reflected or transmitted. If the detector is activated, thus lighting up the bulb, it means the acron has been reflected.

In these conditions, and to answer your question, I should say that along the transmission path goes a theta wave without any acron. I will also add that if a detector is placed along that path, it will not be activated due to the theta wave lowest energy being insufficient to activate it. Do you think I answered your question correctly?

- There is no doubt you perfectly understood the situation and provided us with the correct answer - answered Argus. - Let us now see what happens if we make this minor change to our experiment – and he made some changes to the previous drawing:

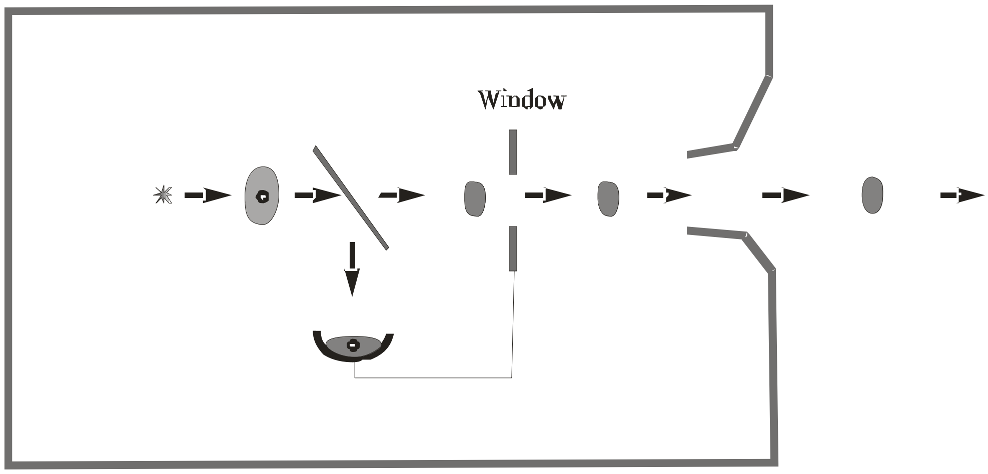


Fig. J8.5. — Theta wave generator (TWG).

As you can see, along the transmission path I have placed a special window connected to the detector. This window is special for being closed at all times, except when the detector is activated. Indeed, it will open after receiving an impulse from the detector and will remain open only for the time necessary to allow the theta wave's passage. Next, this whole device (source, semi-mirror, detector and window) is placed inside a box with one opening, as shown by the sketch. This entire device constitutes our theta wave generator. I believe that after Amadeus' explanation no one has doubts about this device, if the theory is correct, it will emit theta waves one by one. Thus, what we have here is a theta waves generator.

The problem that now arises is to know how we will be able to detect the existence of such waves.

If we place a common detector in front of the generator it will not signal a thing, since the minute energy of the theta waves is insufficient to activate it. It is thus necessary to imagine a process capable of revealing the existence of such waves, that is to say, creating a detector so sensitive that it can react to an extremely low level of energy.

At first sight, it may seem that this task is doomed to failure! However, like everything else, if we meditate a while on the subject we shall see that this problem apparently impossible to resolve has indeed a particularly simple solution, at least from a conceptual point of view.

In order to solve this enigma we must only act like detectives in detective stories and begin by studying the clues, the data we already have. So, what is it that we already know?

From the causal study of the two slits' experiment we know that the theta wave, or guiding wave, has the property of guiding and consequently influencing the course of the acron. Since the corpuscle, or acron, is the only observable entity, what we have to do is to guide it, according to our convenience, using the theta wave produced by the generator.

In order to verify that this idea really works, let us look at this scheme:

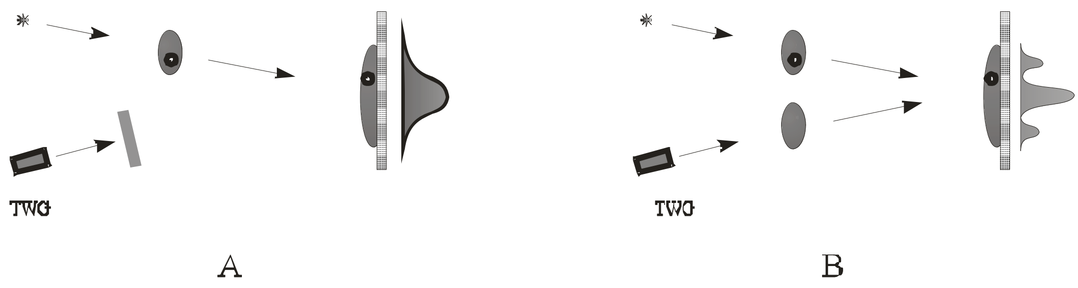


Fig. J8.6 — a) Only one wave reaches the detector. In this case, there are no interferences observed. b) Two waves reach the detector, originating interference. TWG: Theta Wave Generator

Let us assume that the two sources, the common one and the theta wave generator, emit entities simultaneously and at a constant rhythm. As you can see from the first drawing A) the theta wave, originated at the generator, is blocked. In this case, the acron coming from the common source arrives at the detector accompanied only by its initial guiding wave. Since it is a single wave, there is no possibility of interferences being verified. Thus, after some time, the distribution of position of the "clicks" in the detector, which corresponds to the arrival of the acrons, takes the form of a Gaussian. When the obstacle is removed – and he indicates in drawing B) — the theta wave will combine with the other wave originated by the common source. In such circumstances, the acron will now be guided, not only by the initial wave's action, but by the joint effect of these two waves. The overlapping of waves originates, as we know, an interferential distribution. In these conditions, there are now areas in space where the final wave's intensity coming from the overlapping of the two waves is null. Now, as we know, the acron can only be localized in the regions where the guiding wave's intensity is not null. Moreover, it statistically tends to be localized in the regions where this intensity of the total theta wave is maximum. Thus, it all happens as if the acron was escaping the areas where the intensity is null. In other words, after some time, the distribution of the acrons' arrivals at the detection area takes an interferential configuration faithfully reflecting the shape of the joint wave's intensity, as we can observe in the drawing.

At this point Lucius exclaims:

- What a magnificent idea! If I understood correctly, this experiment's possible results are only two:

1) The appearance of interferences. In this case we will have confirmed the causal nonlinear theory over the orthodox theory;

2) No observable interferences. This means nothing comes from the "hypothetical" theta waves generator and we will have refuted the causal theory in benefit of the orthodox theory.

We have here, just like you have said, a "yes or no" experiment. From the results of this experiment we can refute either one theory or the other.

- Everything you have said, Lucius, is entirely true - replied Argus. - Nonetheless, we must bear in mind that we have been discussing a highly idealized experimental situation. In practise, in real experiments that are performed in laboratories, things get a bit more complicated. Notice that in this case we need for the two sources to be perfectly synchronized, and also the theta waves generator must be perfect. On the other hand, there is also a physical imposition, rather complicated to execute in practise, which is called “coherence”. In order for interferences to be observed, both sources must be coherent with one another.

- I have often heard of coherence and coherent light, but to be honest I have never understood well what it is all about. I would appreciate it if you could give me a few words on the subject – Lucius asked.

- I will be glad to! - said Argus. - Indeed, the concept of coherence constitutes a rather complex issue. To provide you with a simple answer, from the formal point of view, I will only tell you that both sources are called coherent when the waves they emit maintain their phase difference constant in time. In order to easily understand this concept we may imagine a choir formed by many elements. Let us suppose that before the maestro arrives, they are all talking at the same time, randomly and to each other.

What do you think, Lucius, will an observer located at the theatre’s balcony listen?

- He will not understand a thing! Since they are all talking at the same time, all that he understands is background noise, which will be as big as the number of elements in the choir – Lucius replied.

- Precisely! - continued Argus. – Since everyone is talking whenever they like, with no time correlation between them, one cannot understand a thing. However, when the maestro begins his piece, all members will emit sounds in a perfectly coordinate way, I shall even say coherent, in a way that at some points the whole room vibrates in unison in a perfect sound coordination between the sources of emission of sound, which in this case are the choir elements. The greater the coordination between the sources, the more coherent is the whole set. Thus, we can say that two sources are coherent when they maintain a correlation or coordination. Naturally, in practise there are no absolutely coherent sources. But it is also true that there are real sources, I am speaking of light sources, whose degree of coherence is extremely high. I am referring to certain lasers.

As long as we are at it, to close the issue of coherence, I would also like to say that the coherence we are speaking of is the simplest one; indeed, there are more general definitions of coherence which naturally include this one as a particular case.

Returning to the experiment for the theta waves detection, in order for this experiment to be significant, the sources must be coherent. Since, in practise, it is very hard to obtain independent and coherent sources, we will need to resort to some experimental tricks in order to perform such experiments. Given the problem’s difficulty, the first proposals that can actually be performed only appeared in the late 80s, in the 20^{th} century. Presently, there is a whole set of experiments, which can actually be put into practise, which can test the real existence of theta waves.

Until presently, quite a few of these experiments have been performed; however, the most significant one was executed in one of the finest quantum optics laboratories in the United States of America, at the Rochester University.

- What was the result of such an experiment? - inquired Lucius.

- Well, opinions diverge on that subject. So that you can have a more concrete and more informed opinion on the subject I will show the experimental results obtained in this experiment – pulling out a sheet of paper, Argus showed us four graphics:

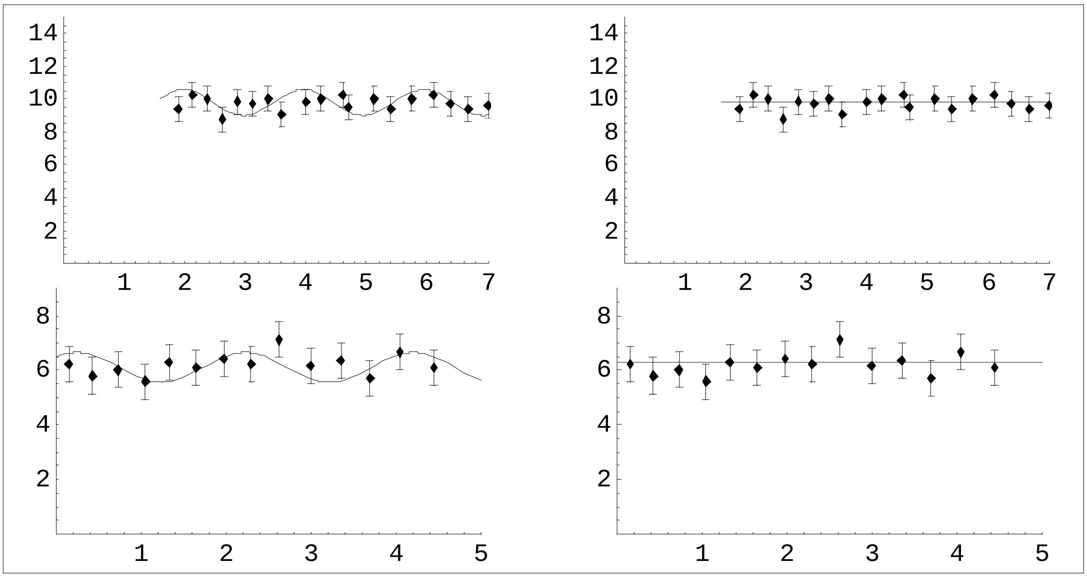


Fig. J8.7 — Results of the experiment performed in Rochester
for the detection of theta waves.

These drawings correspond to two groups of measurements, which are repeated, being the right hand side vertical set precisely the same as the one on the left, as you can see. The dots represent the measurements results and the vertical lines represent error bars. Error bars indicate the precision with which the experimental dot was obtained; that is to say, the real value oscillates between a maximum and minimum given by the bars' dimensions.

If theta waves exist, as the causal nonlinear theory maintains, then we should observe interferences. In such a case, the distribution of dots must follow an undulating wave, cosine pattern. As you can see – and he indicates the first two vertical graphics – this undulating line is drawn in a way that it contains either dots or their error bars.

Since theta waves do not exist for the orthodox theory, interferences should not be observed. The distribution of the observed dots must be a straight line. As we can see, a straight line has been drawn in order to contain the maximum number of dots in the second column.

My question to you, Lucius, is as follows: what do you think of such results? In your opinion, do they indicate that there are, indeed, theta waves, or not?

- If I understood the experiment correctly, the question is to know if the experimental dots observed are placed according to an undulating line or not. If this is so, the experiment will show that something, the theta waves, has caused such an effect. If, on the contrary, they are not placed according to an undulating line, but rather in a straight line, there is no such thing as theta waves.

Now, if we look carefully at the dots it seems to me that they are in fact distributed with a certain amount of undulation. Thus, in my opinion, this experiment has shown that theta waves really do exist. I imagine this was the conclusion the authors of the experiment have drawn, isn't that right, Argus?

- Unfortunately, the authors of the experiment, not only unnecessarily complicated the experimental device, but also drew precisely the opposite conclusion - answered Argus. - Anyway, considering the experimental data made public by the authors of the experiment, and in spite of the indications of a certain undulating distribution, I believe the most cautious conclusion to be drawn is that the experiment must be repeated in better experimental conditions in order to properly clarify the subject.

- Thus, if that is the case, why is it that the authors of the experiment did not try to repeat it in better experimental conditions? - inquired Amadeus.

- Well, the most likely answer is that they were probably afraid of going against the orthodox paradigm. Unfortunately, not everything in science occurs with the openness, clarity and exemption one might expect. The majority of investigators are afraid to contradict the current paradigm, since it would endanger their careers. For that reason, they prefer not to make waves!

- Recently – interrupted Lucius – I have read an article in a rather famous scientific magazine where they spoke of quantum mechanics and its magic, of instant interactions and even actions for the past. While reading the article, from the way it had been written, I was under the impression that it was of an occult, magical or esoteric nature. But what amazed me the most was that everything was mathematically based, or at least it seemed that way. Everything was presented as a simple and direct consequence of quantum mechanics. The least I can say is that I was perplexed. I do believe, however, that it must be possible to show that this is a mystification. What do you have to say about this, Argus?

- You are right. Those people, who are unfortunately more numerous that would be desirable, appear to take pleasure in presenting, generally with great fanfare, certain known facts as if they were entirely new, moreover, in a perspective that makes them extremely complex and nebulous. They are presented as “mind boggling” experiments, that is to say, incredible, impossible to be rationally understood. A sign of the times! We are presently witnessing a true mystification of science. Most of these essays, so-called scientific essays, at the very best, are similar to bad quality science fiction. At least in good science fiction works, the author’s purposes are, generally, clearly specified and developed. These authors do not intend to make science, a domain where the logic rigor and the clarity of ideas are of extreme importance. Looking at some works published today, it seems that the more confused and hermetic a “scientific” work proves to be, the better. The imperative need to clearly specify every base hypothesis, and to follow a line of reasoning which is logically correct in the search for truth, is not at all relevant for those people. Things which are relatively simple are presented in such a confused and strange way that the non specialized reader is completely lost in the midst of such rhetoric, totally deprived of content. What shocks me the most in this wretched trend is that the majority of these authors are not in the least worried with the rigor and clarity of the underlying ideas. Precisely the contrary, it seems such investigators' purpose is to cause confusion and mystification. This trend is so strong that the old and humorous popular saying *to resemble is to be* has become general practice.

What happens is that, when such facts, apparently mysterious, are viewed in the light of the Occam’s razor, when all the garbage and confusion are removed, they become clear and perfectly understandable to every honest and unprejudiced and, especially, reasonable person out there.

There are several lines these people follow, namely the ones related with experiments involving polarization. The confusion they intend to promote may be cleared even in this type of experiments. But since this theme is far from the general public, I will only mention one experiment performed, either with photons or neutrons, where the polarization idea does not intervene. In this experiment, in reports published in scientific magazines, certain not so honest researchers see the proof of retroaction in the past. That is to say, an act made now, in the present, which will have an effect, an action, over something that has already happened in the past. According to these authors, such experiments would prove that it is possible to change the past, which would, in turn, change our present.

To better understand these experiments I will consider, firstly, an interferometric experiment performed with a device called, to honour its creators, Mach-Zehnder interferometer – and he drew:

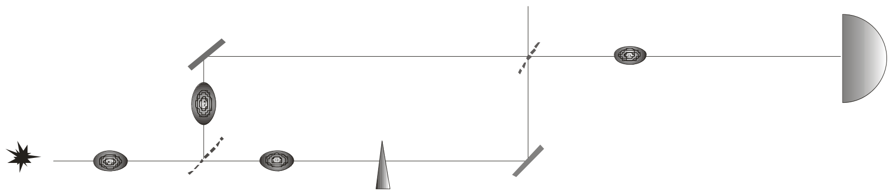


Fig. J8.8 — Mach-Zehnder interferometer

In this device we have a source emitting quantum particles, for example a photon source, two semi-mirrors, two mirrors and a detector. A particle issued by the source enters the interferometer on the left hand side of the sketch.

At this point I would like to remind you that an interferometer is a very special device destined, mainly, to allow the observation of interferences. In fact, this apparatus remarkably manages to produce two coherent waves from an initial single wave.

As we can see, an initial wave will impinge on the first semi-mirror, originating two waves, one that is reflected and another that is transmitted. Each of these waves follows a different path until they coherently overlap again on the second semi-mirror. In this last semi-mirror, each of the waves originates, in turn, two waves.

The quantity of light exiting each path of the interferometers exit is controlled by a device called a phase shifter. In this drawing, the phase shifter is represented by a wedge. In fact, what this phase shifter does is to cause small alterations in the inferior optical path, making it longer or shorter that the one above. If this phase shifter is calibrated in order to make both optical paths precisely equal, as in the case of the drawing, what happens is that the waves heading in the detector’s direction are in phase, while the ones heading in a perpendicular direction are in phase opposition.

In such circumstances, the overlapping of the two waves in phase originates a reinforced wave, equal to the sum of the two.

The overlapping of the waves in phase opposition, exiting vertically, originates a null intensity wave.

In these conditions, all of the light exits in a horizontal direction, while nothing exits vertically. Since the intensity of this wave is null, the probability of finding the particle in that path is also null.

When the optical path is slightly unequal, things are different. The phase shifter can also be set to make waves be vertically in phase and oppositely in the horizontal, thus with all light exiting vertically. In these conditions, no light will reach the detector.

For intermediate values of the optical paths’ difference we will have light on both exits. It all happens as if the phase shifter worked, in practise, like a kind of shutter, a bidirectional valve, shifting more or less light towards one exit or the other.

In short, when the optical path is set in order to allow the two waves to overlap, the amount of light registered by the detector is regulated by the phase shifter.

This registered quantity of light ranges from maximum, when the waves are in phase, to minimum when they are in phase opposition.

Let us now suppose that we change the interferometer so that the optical path above is quite larger than the inferior one. In these conditions, the waves cannot overlap - and he began to draw:

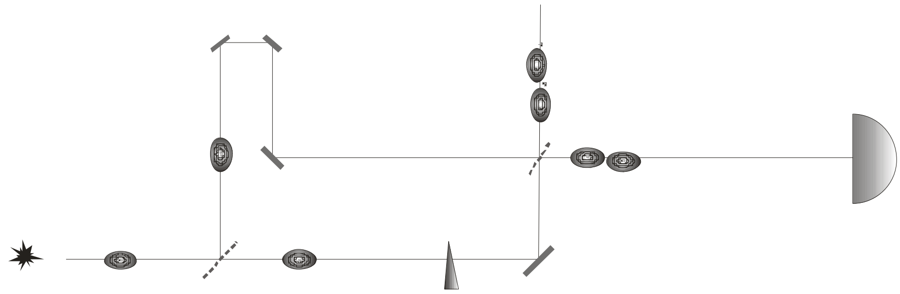


Fig. J8.9 - Mach-Zehnder asymmetric interferometer.

In this case, as you can see, the waves do not reach the overlapping area constituted by the semi-mirror at the same time. In these conditions, like we can see from the drawing, there are no waves overlapping. It all happens as if the waves have independently arrived at the last semi-mirror.

Consequently, each of them is partially reflected and partially transmitted. Thus, in each interferometer exit two independent waves follow.

In such conditions, the conclusion to be drawn is that the action of the phase shifter device, which, as we have seen, consists in causing minor changes in the difference of the optical paths, has no effect on the intensity measured at the interferometer exits.

Another way of describing this very situation is to say that when the difference of the optical path is greater than the size of the waves no interferences are observed.

Let us now see what happens when we place a monochromator in front of the light emitting source in order to increase the coherence length of radiation. The coherence length of a wave corresponds to the extension in space where the wave acts. In this case, it all happens as if the initial wave became longer, as we can see here:

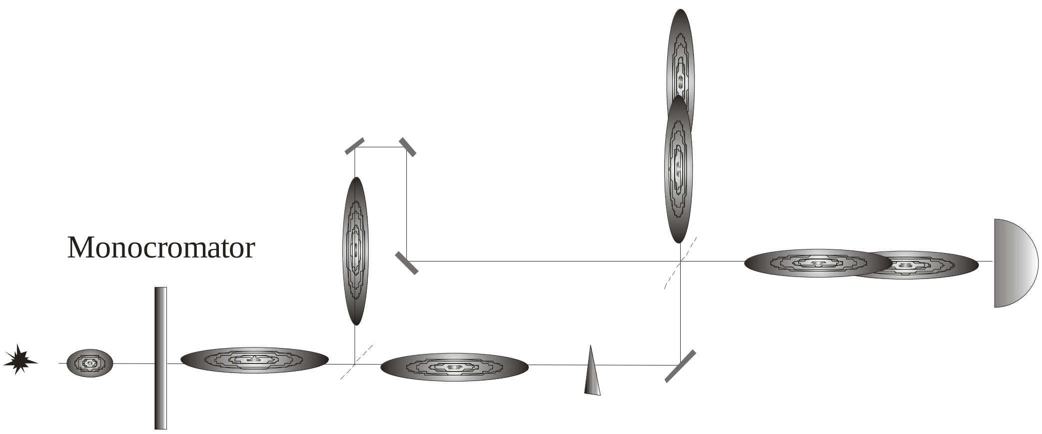


Fig. J8. 10 - Asymmetric interferometer.

Since the coherence length increases due to the action of the monochromator, the waves arriving at the second semi-mirror will now be able to partially overlap. I must point out that, in spite of the coherent wavelength increase, its intensity will decrease. Generally, this intensity reduction is as big as the coherence length of the wave exiting the monochromator.

At this point, Argus paused and turned to Lucius, asking:

- Do you think that in this case we can vary the amount of light reaching the detector through the observer's action on the phase shift device?

After some meditation, Lucius answered:

- I believe so. In this case the waves will overlap again. If there is overlapping, even if partial, we can have situations in which the part of the overlapping waves are in phase or in phase opposition, or any other situation in-between. We will be able to regulate, within certain values, the amount of light exiting the interferometer and "seen" by the detector.

— Great, you have given us the correct answer! - continued Argus. - In this concrete situation it is possible to observe interferences, which will be more visible as the overlapping of waves is greater.

Let us now see what happens if instead of placing the monochromator right at the source exit, we place it immediately before the detector:

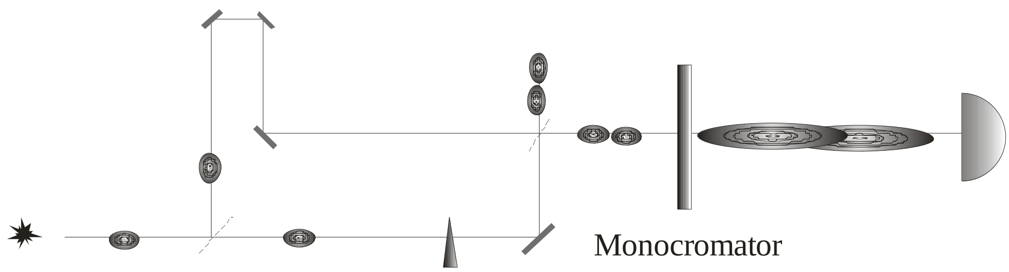


Fig. J8. 11 - Retroaction in the past experiment?

The question that now arises is to know if the amount of light registered in the detector depends on our actions on the phase shift device. In fact, what matters is to know if there are, in this case, in spite of there being no overlapping, interferences in the area of the two waves' juxtaposition.

What do you think happens now, Lucius? Will interferences be observed, or not?

- Now - answered Lucius, somewhat perplexed – I do not really know what to say. At first sight, I would say there should be no observed interferences, since there is no physical overlapping between the waves. However, since I know that in these quantum mechanics issues things are generally more complicated than they seem at first sight, I do not really know what to say.

- As you may have suspected by now - proceeded Argus, resuming his speech – after all that has been said, in this experiment, and in such conditions with no overlapping of waves, interferences are indeed observed. That is why we call this experiment non-local interferometric experiment.

Our problem now is to explain the observed results in an understandable and natural way, with no need to invoke mysterious occult actions, to invoke magic or even some other more transcendent behaviours.

In order to do so, we will observe this experiment a bit more attentively. The process generally used by some authors, who claim to have based their reasoning in the orthodox theory, overlooks extremely relevant aspects. This is a perfectly understandable attitude, since the purpose of such authors is to not present an understandable description of natural facts. On the contrary, they take great pleasure in presenting, whenever they get the chance, an image of the facts that is as confusing and unexplainable as possible.

Let us now find out more about these relevant factors, either from an experimental or a theoretic point of view:

1) The monochromator's action, as we have seen, corresponds to a sort of filtering, this means that from the initial impulse the monochromator will select only a certain group of frequencies; that is to say, it will only allow the passage of a relatively narrow band of frequencies. Just like when we place a green glass in front of the sunlight, which is white; in this case, it only allows the passage of a narrower band of frequencies, corresponding precisely to the green colour. In the limit situation of an ideal monochromator, it would select only one single frequency.

In this limiting and definitely ideal case, in which only one single frequency exits the filter, two interpretation possibilities are open:

a) Fourier ontology (orthodox quantum mechanics):

In this case, the monochromator selects one single harmonic plane wave from the original finite impulse formed by numerous harmonic waves, each with its well defined frequency. In this ontology, this wave is, as we know, the only one that has a perfectly defined frequency. Since this wave has a spatial infinite length, no matter how great the difference in the optical path may be, the two probability waves will always overlap at the interferometer.

b) Causal local and nonlinear paradigm (wavelets):

The monochromator's action corresponds to the selection of a finite wavelet with a well defined frequency and with a finite length. In this case, while the difference in the optical path is smaller than the wavelet's length, we will have interferences. However, when the difference in the optical path is larger, and consequently there is no overlapping of wavelets, we no longer observe interferences.

2) The impulse entering the monochromator has a much bigger intensity than the one exiting. This intensity decrease is a function of the bandwidth of the monochromator. The narrower the bandwidth is, the smaller the intensity of the exit impulse.

3) From the two previous points, we can conclude that in our experiment, since there are observed interferences, there is always a wave juxtaposition even if more or less partial, at the overlapping area. This happens, whether the filter is placed before, or even after the interferometer. This overlapping occurs, as we have seen before, even in the Copenhagen paradigm, contrarily to what some authors imply. This more or less partial overlapping of waves, always present, is generally masked by many authors, who use the orthodox paradigm incorrectly, by abusing mathematical formalism.

Within Fourier's non-local and non-temporal ontology, we must also point out that these affirmations of non-local interferences and of retroactions in the past correspond indeed to a tautology. Obviously because, in this ontology, as we well know, space and time do not play a relevant part. In this case, no true separation in space and in time is actually possible. One single entity, as we have seen before, includes all space and all time. In this sense, separability is merely chimerical, a mere illusion of the senses.

The causal paradigm, more general, states that the interference is always the result of the physical overlapping of two or more finite real waves. These physical waves, finite and real, selected from the initial set by the monochromator, will overlap whenever the difference between the two optical paths is smaller than the wavelets' length.

4) Another significant point to consider is the fact that there is interference whenever two or more finite and real waves occupy, at a given moment, the same area

in space.

Whether or not such interference is observed with the aid of the tools available to us is an entirely different matter.

Many times, it happens that this interference is masked by noise made by other waves. In spite of there being interferences we have no chance of observing them.

In order to understand this situation better, let us think, for example, of two people chatting tranquilly in a large room. In this case, what they say can be perfectly perceived.

Let us now suppose that other people arrive, until the room is now full. When they all speak simultaneously it is no longer possible to understand what the first two people in the room are saying. The background noise is such that it completely masks what they are saying. But they still can understand each other.

Once exposed to the relevant factors involved in any interferometric experiment, the causal explanation becomes evident. Let us now see what happens:

Our source emits particles randomly with a perfectly defined energy. Each particle, as we know, is formed by its guiding wave and by the acron. This basic fundamental wavelet's length must always be superior to the difference in the optical path, if not no interferences would be observed. However, the impulse exiting the source is the result of a combination of many wavelets. In technical language this overlapping of waves is called a package, or even a train of waves. This package of finite waves corresponds to a sort of average resulting from the whole set of particles, and therefore of waves, emitted during the impulse. The length of this wavelets' package is, as we have previously seen, smaller than the length of the basic mother wavelet. When the difference in the optical path is superior to this length, as in the case of this experiment, there are no observed interferences. However, if we place a filter, a monochromator, before or after the interferometer, the length of the wave package will increase. As soon as this package's length is greater than the difference in the optical path we will again observe interferences.

- To be honest, Argus, I did not understand your explanation very well – Lucius interrupted.

- Let us see if I can make things clearer with an analogy - continued Argus. – In a more simple language, we can assume that it all happens in that very crowded room we have mentioned before, with everybody talking to each other at the same time. Groups of two for example. It is clear that in each group if two people are close enough to each other, they can perfectly understand one another and their conversation has a meaning. However, since all these two people groups are simultaneously chatting independently from one another, all that a distant observer can understand is incomprehensible noise. In this case, in the midst of such racket, it is not at all possible to understand the conversation that is made in each group. However, if we begin to evacuate the room, in order to reduce the number of two people groups, at a certain point, we will be able to glimpse the meaning of some conversations. The less people remain in the room, the better we understand the conversations. At the limit, when the number of people is reduced to one single group, we can clearly and perfectly understand what is being said.

Argus paused. He looked at Lucius and inquired:

- Was I clear enough?

- I believe things are clearer now - answered Lucius. – Let us see if I understood it correctly. In this experiment there are always interferences, that is to say, the phase shift device can modify the way in which the waves coming from the two paths overlap. However, since the conversation each pair is having cannot be understood, due to the presence of hundreds of other conversations, here the interference of the two waves, each coming from its own path, cannot be observed either, since it is masked by the general noise. As the filter eliminates other waves, the background noise decreases. At the limit, when we have only two waves produced on the first semi-mirror and resulting from one initial wave, each following its own path, their interference is observable once more.

The interesting part of this story is that the observation of interferences is totally independent from the existence of a filter before or after the interferometer. We now see clearly that there is no action from the present over the past.

- Exactly! - Argus exclaimed. – As I have said initially, this experiment can be perfectly understood by anyone with good sense and an open mind. In order for this to happen, it is sufficient not to have one's spirit fossilized by obsolete prejudices and, above all to follow a sane causal line reasoning.

I would also like to point out that this is an important experiment because, besides its conceptual significance, it constitutes also an empirical tests for Fourier ontology. Playing with the monochromator's bandwidth and the difference in the optical path we can see if the interferences are no longer observed when the difference in the optical path is superior to the maximum coherence length. This maximum coherence length is, in the causal and nonlinear interpretation, as we know, the length of the mother wavelet. In Fourier ontology, that is to say, the orthodox interpretation of quantum formalism, interferences are always observed, since the coherence length, the size of the harmonic wave is, ideally, infinite. However, even in real and concrete situations there is a difference between the predictions of the causal nonlinear theory and the predictions of the orthodox quantum theory. I believe it would be of importance to perform this experiment with maximum rigor, since it could highlight the applicability limits of the orthodox quantum theory.

- This experiment must be faced with seriousness and objectivity and without trying to create completely unnecessary confusion. In spite of everything, it is presented by some authors as a manifestation of the irrational. In fact, everything is handled as if it were a magic show. The numbers the illusionist performs are presented in such a way, surrounded by so much mystery, that it might seem we are witnessing true miracles. If we go backstage, with a free and inquisitive spirit, we can understand the trick being used and all that has seemed magical, mysterious and unexplainable before, is now perfectly understandable and natural. The explanation we have provided for this experiment corresponds to observing it from the backstage. As we have seen, there is no mystery to it.

After Argus' intervention, silence was broken by Lucius:

- From what you have said and from what I have learnt, either from reading or from the dialogues, I reach the conclusion that there is a whole set of forces, more or less occult, seeking by all means to obstruct the progress of human knowledge. And you know what else? In the middle of all this, what astonishes me the most is to verify that, in spite of all the difficulties made clear throughout our dialogues, there are still people trying to understand the world surrounding them on their own.

Argus regains the word:

- On modern causal and nonlinear quantum physics there would be much more to be said. Many more experiments could be discussed, also presented as pretentiously unexplainable by less sincere researchers. However, as I have had the opportunity to refer, these are experiments involving relatively complex concepts, like polarization, or spin, and others. An adequate treatment of such subjects would demand using a relatively complex mathematical formalism, or alternatively, giving explanations which would take us forever. The examples given so far are sufficient to give you an idea of the present state of the discussion regarding the foundations of quantum physics. We can thus verify that it is necessary to return to a more solid basis, which could support men's natural aspiration of understanding the world; of making science; of making physics. The history of physics after the Second World War emphasizes the feeble progresses made, in spite of the large human and financial investment.

I believe that, for now, it is better to end our discussion and meditate on what has been said. As you know, knowledge is not obtained by discussing an infinity of subjects, or simply by reading a huge amount of books. This is almost always the dilettante's attitude, since he has a rather vague idea on almost every subject, but, in the end, there is very little that he really knows about. Whenever he speaks, he never expresses his own ideas, since he possibly does not have them. His speech consists solely on a more or less chained plead of quotes that quote several authors which generally are viewed as great authorities on the subject. In the end of their speeches, if we are discourteous and bold enough to ask them for their personal opinion on the matter, they will simply refuse to provide one in every way. What we indeed have to do, in order to progress in knowledge, is to study the few really important works, and above all, to profoundly meditate on the questions which have arisen. It is not the quantity that matters, but the quality. Otherwise, we are taking the risk of drowning in a sea of information that we cannot even manage, let along understand.

The fundamental problem of physics is, as we have seen, since 1927, the wave-corpuscle duality. Until we can free ourselves from the Bohrean interpretation of such dualism, we will not be capable of innovating physics; innovate in the true meaning of the word. That paradigm is long worn out. An American physicist, Oldershaw, wrote an article in 1988 in which he claimed that the physics of the time, that is to say, the main current of physics, was dedicated to construct first and second level unverifiable "theories". The first level theories are those which, in order to be tested, require nowadays unreachable energy levels. Therefore, they cannot be tested. The second level theories are those which depend on so many parameters that, whatever the experiment result may be, we can always adjust those parameters to make the "theory" comply with the result of the experiment. It is easy, in that way... Just like it is easy to win the lottery after the numbers have been announced. *A posteriori* it is always possible to find a justification for the numbers that have already been raffled. The hard part is to win the lottery before the raffle...

The experiments we have discussed are perfectly performable with the technical capacities of today. In these conditions, the only decent thing to do is to perform such experiments with care and verify their results. We know that nowadays it is as hard to fight preconceived ideas as it has been before our time. Maybe that is the reason for the real fear that exists when it comes to confronting "scientific wisdom", the currently accepted scientific dogma. Let us not forget what happened to Emil Wolf.

Emil Wolf is a consecrated physicist that wrote, a few decades ago, a famed treatise on optics, together with Max Born, *Principles of optics*; and more recently, another treatise called *Optical coherence and quantum optics,* on quantum optics, together with Leonard Mandel. Besides that, he has a remarkable work published in several scientific magazines. Now, at a conference, Emil Wolf decided to claim, in consequence of his theoretical investigations on photonic statistics, that in given conditions the light emitted by a star could suffer a deviation towards red while crossing the nearby space. He was given no opportunity to speak, he was booed and whooped. "Excellent" arguments to criticize his proposal... Things are looking strange in the world of physics...

- It seems to me, Argus, that you are speaking of incidents I believed to be possible only some centuries ago! I am glad we do not condemn people to burn these days... – Lucius exclaimed.

- Quite true... - continued Argus. – The intolerance I have mentioned is not that different from the one that condemned, for example, Giordano Bruno to burn in 1600. Even those who intend to submit to the validation criteria of a scientific theory are attacked. They are attacked by those who dedicated their whole lives developing a certain conception of the world that is evidently worn out. They feel betrayed because they put themselves on the line for a given theory, they bet more than anyone should bet. To prove the insufficiencies of such theory is not a synonym of attacking the ones who have dedicated their lives to it. We must never settle for a given conception of the world; it will always be provisional and I will be the last one to be settled. Science is no more than the humble but persistent search for the deep meaning of the book of Nature. This is a meaning which we are all far from having deciphered, since we only have had access to the first pages. But, even if we only have accessed the first pages, science is already a hymn to the human reason. And it will continue to be so.

We all remained silent for a while. We were finally conscious of how late it was and how it was inevitable we close the Dialogue.

- Perhaps later it will be possible for us to continue. There is much more to be said - Argus announced.

DIALOGUES ON QUANTUM PHYSICS
from Paradoxes to nonlinearity

The old paradigm of linear quantum mechanics is worn out. It is therefore urgent to replace it with a new approach, one which accepts a reality independent from the observer and which solves the paradoxes and enigmas that popular theories continue to stimulate.

This book, in a language accessible not only to scholars but to everyone, exposes the insufficiencies of the orthodox and dominant linear quantum physics, and also demonstrates that time has come to bet on a new quantum physics, a causal and nonlinear physics, which for the time being is heterodox.

We are invited here to view the most outstanding events in the history of astronomy and physics; we are also confronted with the epistemological debates that prove decisive to the future course of this area of knowledge; moreover, we are led to re-evaluate many conceptions which are, after all, fallacious, and supposedly integrate «true science»; and finally we are led, in rigor and clarity, through the meanders of an innovative interpretation of quantum physics, based upon the complexity and nonlinearity, which will be the foundation to the most promising research programmes.

ESFERA DO CAOS
EDITORES