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On the origin of Einstein's electromagnetic radiation theory

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(English translation Laura Di Giuseppe)

Works of art thrill the spirit. No one can be aware of Einstein radiation theory without feeling joy.
Daniel Kleppner, *Rereading Einstein on Radiation*

Abstract. The 1905 fundamental paper by Einstein on quantum electromagnetic radiation is considered the starting point of modern physics. The International Year of Physics 2005 was a great occasion for analyses of the disciplinary contents of Einstein's works. In particular the present contribution tries to show the characteristic features of Einstein's genius, by reviewing his 1905 paper. This plurilinguistic work is not apart from this perspective, as the translation in itself implies more careful attention on the contents starting from Einstein's mother tongue. We started from the original text, supported by the recent conquests of neuro science, with the aim of supplying schools and educational institutions with a cultural and research product that, on one hand supports the plans of disciplinary communication in a second language, including the local language, and on the other tests the effect of plurilinguistic communication on stimulating the mind to pick up the innovations and to devise new solutions. This objective, very important for all the mother tongue readers, is also intended to show that friulan can confront the challenge of scientific language.

Key-words. quantum radiation, pluri-language, neuro-language, mother (local) tongue, black body (cavity radiation), entropy, quantum energy, photoelectric effect, oscillator, microstate.

1. Introduction. Before introducing Einstein's papers in 1905 on the nature of light and the following ones in 1906, a few considerations on the motives for the choice of papers and studies rather than more famous works are needed. Einstein' paper on the "light quantum radiation", a

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problem joined with that of the photo electric effect, is one of the five, if we insert into the list also the publication of his bachelor thesis, he published in what has been called the "miracle year".

In the following year, 1906, Einstein wrote an article on the subject of light that demonstrates the maturation of what he had written a year before on the hypothesis on quantum light and concludes with an unexpected illustration of an ideal experiment that recalls the Volta effect. This personal "heuristic" approach to introduce the tests of his intentions by means of "only thought" experiments will be called in German "gedanken experimente".

In fact, in the illustration of the 'thought experiment' in order to link Volta's contact voltage with the frequency of light photons, there is no hint, and it could not be otherwise, of the energy band theory that will emerge many years later. Nevertheless, this paper opens a window on the possibility of putting in motion electrical charges propelled by energy photons beating junctions built up with different chemical solid layers, a phenomenon that years later will be called the photovoltaic effect. So, we can then join to the hundredth anniversary of Einstein's 1905 paper, the other one in 1906 that links for the first time in the physical science the photoelectric and the Volta's effect. But at this point let's look at the 1905 year and browse through Einstein's papers starting from the most famous ones. Before all else comes to the mind spontaneously the work referring to "relativity" that has deeply marked the collective mind. It is also the paper that more than any other has led to a parallelism with the artistic representations of various people of letters and artists. In short we can consider experiments in literature with novelistic plots lacking time sequences: a list of topics described in sequential pages but without a versus, or a leading thread, from the beginning to the end. A literary style that has introduced into essay and novels the rejection of temporal sequences such as in the pages of the works of James Joyce (1882-1941, Robert Musil (1880-1942) and Virginia Woolf (1882-1941), authors who have written in the years around 1905. Then let's remember the visions of the energy of the atom in artists like Salvador Dali (1904-1989), up to the anthropological cosmos pictures born from the relativity theory in the short stories by the Italian Italo Calvino (1923-1985) more recently. Here we have chosen to cite the names of the authors who are perhaps the most popular among those who, referring to our readers, have followed the high school curriculum.

But if the cognitive baggage of the 1905's paper on relativity (special) is more appealing for the exotics trips that it promises, ideas expressed in a lot of films also of high quality, it's also the most difficult to express because the concept of simultaneous events contradicts our intuitive ideas. Anyone who wants to bring a knowledge of physics and research to a wide group of people who are not highly motivated students of science has to find a suitable didactical method if he does not want to renounce to the conceptual rigour necessary to prevent mismatching. This necessity often puts a restraint on the readers natural inclination to go on and not to stop to reflect; it abruptly dampens the attention to the flow on the written page. So the reader feels forced to complete hard manoeuvres, to proceed beyond in order to temporarily avoid demonstrations or to stop for entering in a new way before re-entering and resuming the path. But it can happen that he considers the mathematical formula in front of him as an unexpected obstacle to be avoided by moving quickly to the next line, or, worse, to stop reading and put back the book on the shelf. There is the risk of surrendering to these difficulties and accepting unsettled figures, still distant from the concepts.

We still think that Galilei's point of view expressed in the *Saggiatore* is valid nowadays; it writes that we cannot "understand… the enormous book that is opened in front of our eyes [I say the universe] […] if before we haven't learned to know the language… with which is written… without these [characters] we bring ourselves around in a dark labyrinth". For some subjects this "manifesto" of physics can be moderated, for others less. In the case of the article on relativity, it is also true that the mathematical instrument is elementary but an author who does not want to renounce to the necessary compromise between rigour and simplicity will find himself in the necessity to not only slim the formal apparatus of mathematical character, avoiding to expose too many mathematical acquaintances advances, but also to complete it with figures and animations. A task of difficult realisation and far from our skill.

Therefore there is no other choice than considering the other four: on "equivalence between mass and energy", on the "determination of the molecular dimensions", on the "brownian movement" and on the "photo electric effect". Shortly let's consider the motivations that have pushed us to choose the last one.

The topic that turns out to the famous formula of the dependency among the energy, the mass and the square light speed is an extension of the work on the relativity, and therefore it would be strictly close to the main one of which, some lines up we have said the reason for which it has been decided to give up. On referring the bachelor thesis work on the molecular dimensions, it is so full of formulas to make the reading of the literary text completely secondary. It remained to decide between the work on "the brownian movement" and the one on "photo electric effect". Both would have lent to a pluri-language translation, analysed and discussed.

Finally we decided to choose the "photoelectric effect" work for two reasons, leaving aside the fact that this work was awarded a Nobel Prize in 1921.

The first one arises from an epistemological opinion that has been shown by various scholars. While the work on "relativity" and 'equivalence mass energy' is today considered by the physicists, more than a split with the classic theories, a point of maximum expansion of the tradition of the classic thoughts of Maxwell, Lorenz and Poincarè, the work on quantum hypotheses of light truly makes a break with the classical tradition.

The other motive arises comes from the experience that the AIF of Udine has acquired working on innovative teaching and spreading scientific culture. Since 1999, two hundredth anniversary of Volta's discovery of the electric battery, the Unit has held conferences and made experiments with battery and photovoltaic cells, in order to updated physics teachers and also to begin to introduce quantum physics into High Schools in Udine favouring the aims of the Physics Didactical Research Unit of Udine University. In particular we compelled ourselves to complete a research work on the origins of quantum physics beginning from Einstein's 1905 and 1906 papers.

In conclusion, we have been nearly obliged to turn out the attention on this article.

Finally we want to explain why we translated Einstein's topics into friulan, a work perhaps harder than our forces and competences permit.

We estimate, with little belief, that the number of readers in friulan can be counted on the fingers of one hand and are mostly high school teachers. Middle school teachers will mostly use text books or books in Italian that normally do not give historical sources. More demanding teachers try to extract specific facts from Italian or English books written by famous names of the academic world.

Moreover, considering that we have little contact with school teachers, we hope at least to carry out some CLIL[1] didactical experiments in friulan.

Where can we catch more readers? Is it possible to find anybody among the readers prepared to read in friulian a minority language? We think so. In particular all the subscribers to the *Gjornâl Furlan des Siencis* are potential candidates. I hope they can enjoy reading until they need to go further, to find some answers to questions that they would not have asked if the text had been written in Italian or English. And then we hope that this work will become known outside the close circle of the SSTeF[2] and at the end finally be seen in other hands: friends, relatives, collaborators, finding it in the shelves of libraries of Friuli and in the schools. It is this perspective above all that has helped us to fulfilment this work.

This is our first goal with reference to physics development. In the following paragraphs we will point out two problems, not connected to respect Einstein's physics explanation, but that we want to emphasize because on one hand one of them concerns our personage and the other one the role of language in teaching (physics in particular). Nevertheless it would be interesting to carry out specific checks in a systematic research work.

Pluri-languages and Geniality. The choice to closely examine the topics of Einstein’s paper on energy quantization and the plurilinguistic context of the SSTeF has stimulated two questions apart from the new physics in Einstein’s 1905 paper.

Might a plurilinguistic work help discipline learning and, consequently, is a native local language (the mother language) able to transmit disciplinary contents with the same effectiveness as the second language?

What is a genius: a person with ideas and a brain nobody else has, an alien species, or are there other characteristics that permit us to recognize them?

Let’s first approach the effectiveness of plurilinguistic learning, a factor closely related to the survival of minority languages.

SSTeF has been the ideal container in order to emphasized a plurilinguistic deepening work.

Considered that the aim of SSTeF is to spread cultural contents and research in friulian, we had to start from Einstein’s original document, that is in German, his mother tongue. So, a parallel work has been carried out between the various texts in German, English and Italian before a final translation into friulian. It has been shrewdly noted that some steps in the passage from the original text to the second language have not been always completely understood. The successive work to look for words and phrases proper for the text in friulian later obliged us to seek the concepts of physics that the author truly wanted to express. Using this technique we hope to have turned out a text written in good friulian, we hope better than any rush translation into Italian or English.

Another purpose of this work, focused on learning modalities rather than on the acquaintance itself, is to foster modern neurolinguistic science research and support its developments. Research in the medical and pedagogical field have drawn some conclusions on plurilinguistic communications efficiency. The placement of these scientific discoveries into a school means testing teaching approaches, beginning from the mother tongue, in order to evaluate the level of understanding. Some experiments on drive-language learning in high school are encouraging[3] but it is necessary to create a full learning plurilinguistic environment at school to assess it completely.

Neurology research puts in evidence that mother tongue, orally learnt, and organized in the structure of the procedural memory, if employed as drive-language written and spoken contributes to declaratory memory formation to useful communicate scientific concepts normally driven by second languages; in other words it is the organized areas of the brain normally occupied by the second and third languages that are released to work. The mother tongue becomes a vehicle that stimulates attention because it recalls an emotional world present since childhood and so stimulates study. It’s a question then of extending the mother tongue, used as a drive-language, to the zones of the brain organized to elaborate concepts more easily occupied by second, third and so on languages. In this way we enrich lexical knowledge indispensable for saving a language in a global world. Einstein spoke and wrote about issues in a German linguistic area and had to concentrate a lot in order to produce new ideas and wonderful solutions. But in order to introduce his ideas and theories he had to speak in English (he also spoke and wrote a little in Italian[4]) and others have undertaken the task of translating all he wrote into all the languages of the world.

Scientific creativity seems to emerge at an early age, in that period of life when the search of identity comes to an end. A younger person closely involved in some field of science gathers information from a plurilinguistic source but normally thinks in the local language, often the mother tongue. It would be very interesting if research established a connection between the mother tongue and a plurilinguistic meaningful context to explain the “explosion” of creativity. Is this the key to explaining, at least in part, early ideas and insights, clearly and concisely set out exposed, to explain what is commonly called a “genius”?

If a local language dies, the world becomes poorer. If a minority language is to be saved it is vital to construct a heritage of books, materials and experiences that gather all the new words introduced from second and third languages without compromising phonetic and syntactic structures of the primary language through which people express their identity.

In any case we are convinced that this operation of friulan valorisation utilized as an instrument to disclose high scientific concepts has not lowered the threshold of effective communication in regard to more widespreading languages. As regards the second question, it involves historic papers and studying physics as is shown in the following paragraphs.

Einstein, a genius fallen from the sky? Now we can start to develop the weft of that great adventure of the thought from the letter he writes to a friend about the first 1905 topic: “I promise to send you four articles […] the first one I could send you for the short ways, considered that I will have the copies. It is about radiation and energetic property of the light, and is very revolutionary, as you will see”. Einstein considers this article “revolutionary” and later shows that he realises that the content will be disputed before being accepted; and not only because he was not part of some academic group. In fact, even after a century we recognise that with this work Einstein contributed greatly to building a new physics: quantum physics.

How did Einstein arrive at this extraordinary result? This question hang mainly on the “revolutionary” bearing of his work published in 1905. Before pondering with attention the first issue with the aim of understanding the absolute innovation of the contents exposed there, we shine the spotlights on the person, then unknown employee of the Bern Patent Office, that introduces himself to a large member of contemporary scientists and that will throw the abashment in the rows of the conservatives.

We wonder: "Einstein … was he really the great genius that appeared out of the blue in the history of humanity, and from nothingness discovered wonderful laws, up till then hidden from the eyes of everybody?". This is what most people think without question. Another genius born two centuries before, Isaac Newton, had the intellectual honesty to recognise a great truth: "If I have seen further, it by standing upon the shoulders of giants". Einstein did not repeat that, but in his papers, citing the works of many scholars he says the same thing to us. Also Einstein, the antonomatical genius, had to climb on the shoulders of giants in order to see further, much further. Others did this, but they did not succeed as he did.

This new physics criticizes the universal validity of Maxwell's theory of light. Surely Einstein doesn't surpass Maxwell's theory that: "it is unlikely ever to be replaced", but at the same time if we look carefully at light emission and the transformation phenomenon we must consider the atomic structure of matter with which: "the energy of a ponderable body can be written as a sum over the atoms and molecules". After a few lines he concludes: "that theory […] will lead to contradiction with experience if it is applied to the phenomena of the creation and conversion of light". It seems that this was the first hint that led him to the discovery of the second nature of light, the "corpuscolarity".

This idea in itself was not new nor particularly "brilliant". For centuries man wondered on what was the nature of light. In relatively recent times we find at the dawn of modern science Galilei who wrote in *Il Saggiatore* (1622) that light can rise from the flow of "ignicoli", very thin, penetrating corpuscles. But the leap from pure speculation to supporting scientific analyses is made by Descartes and Newton who investigated the effects produced by the interaction of light with matter. The first one repeating the medieval experiments on the passage of luminous beams through water spheres and the second observing the decomposition of white light through a prism[5]. Both were based on the corpuscular hypotheses of light[6]. Einstein, more than two centuries later, was able to climb onto the shoulders of Newton as well as those of contemporary giants.

In fact, before moving his "cavalry" Einstein was able to stand comfortably particularly on the shoulders of Ludwig Boltzmann and Max Planck. The two had smoothed the way for the new campaign of attack on the old conception, having resolved the main problems of black body radiation. From those heights Einstein was able to observe the new horizon with sharpened sight and conceive a new strategy to overcome the weak points of conservative ranks. This new "revolutionary" idea took root slowly while conservative ranks became thinners. From the start the new army conquered not only small territories but whole continents.

Let's go on to the giants' shoulders and those of lesser people, and with Einstein's help follow his thread of though to understand the path of his genius.

The state of physics in young Einstein's age and the hypothesis of the "corpuscles" of energy. In order to understand Einstein's papers, we must cast a glance at the state of physics, that is the level of understanding and knowledge of the fundamental physics concepts in the scientific community in the early eighteenth century. We know from Einstein letters that as a young student in Zurich he had studied some of the best works in thermodynamics, electromagnetism and mechanics and successively he could keep in touch with new fields of physics, looking over proceedings and sufficiently update books.

Considering the importance of the concepts "black body radiation" and "entropy" in the context of papers, some considerations are necessary on Einstein's progress.

The concepts of black body, or "black radiation" or "radiation of cavity", are of fundamental importance in all the processes of absorption and emission of heat and light (from the oven for baking bread to stars). The study of these ideal physical objects has led to the formulation of laws that allow us to measure the temperature of distant objects like the sun and stars but also the temperature of warm bodies from incandescence up to melting point. Studies and research on phenomena of heat emission and adsorption of bodies had a spin-off in the applicative fields if we think that industrialized societies at the beginning of the eighteenth century had learned to master heat to use internal combustion engines in mechanical work and to produce metallic alloys in furnaces at high temperatures. There is great interest in improving the transformation of heat in mechanical work in order to save money and resources.

Entropy enters in all energy transformations, from the cooling of a cup of milk and coffee to the behaviour of a black hole in the universe, but in particular entropy has a fundamental importance in processes involving energy flows in natural and mechanical systems. In the first energy flows involve biochemical transformations fed by radiant energy from the sun and this produces an increase in information and consequently a decrease of entropy; in the second energy transformation of heat in mechanical apparatus recalls a problem of process losses or efficiency, that means that heat in no way can be transformed entirely into mechanical work and so the entropy increases. Considering that all work energy transformation processes, natural and manufactured, are irreversible, heat loss flow, scientifically called entropy, enters straight into the applicative physical quantities field.

We begin our survey starting from the black-body concept and then we will take into consideration entropy. Finally we will reach the stage of introducing the heroes of the entire vicissitude: "quantum energy" and its mentor.

The common and quick definition of a black body is that of a body that absorbs all the incident radiation that falls on it. This definition is not satisfactory if we consider that a system very close to the ideal model of black body is the Sun… that "is far from black"!

We can appreciate the distances between spontaneous ideas of common people and normalized physics definitions, if we read the point in his paper where for the first time Einstein spoke about the property of a black body. The term "black body" is cited six time and at the fifth we can read: "In the event of the 'radiation of black body', ρ is a function of υ such that the entropy is maximum for an assigned value of the energy", where is the density of radiation for a determined frequency, and υ the frequency.

The step demonstrates that the young Einstein for a long time was familiar with current scientific knowledge. In effect to grasp the abstract concept of a black-body we have to start from the property of the energy density of the cavity radiation held to constant temperature. that is: a) the density has a same value in every point of the volume of the cavity, b) the density depends only on the temperature of the cavity walls and c) the spectral distribution referred to temperature does not depend neither on the nature of the walls and the shape of the cavity. The property, described with a formula by Gustav Robert Kirchhoff (1859) and deeply expounded by Planck, is satisfied if the walls absorb all the radiation and do not reflect any.

We can experimentally measure cavity radiation of all spectra if we make a small hole in the cavity walls, maintained at constant temperature. In this way all the radiation that passes through it remains caught for very long time in the cavity[7] that is to say that the hole absorbs all radiation falling on it (and crossing through it) and it does not reflect any part of it. But considering that the wall cavities are maintained at a constant temperature, we can deduce that the amount of absorbed radiation must be equal to that emitting (through the hole) and then we can conclude that the radiation emitted from the hole enjoys all the properties a), b) and c).

If then the cavity is maintained at room temperature the hole appears black at first sight because the emitted radiation is invisible (heat); at this point the cavity radiation has all the rights to be called "black radiation"' or "black body" (see Figure 1). If instead we bring the walls of the cavity to very high temperatures (as an example to 2000 K in a tungsten cavity), the cavity walls becomes incandescent (see Figure 2). We have digressed in order to show the fact that a black body is not ever… *black*! The Sun, that satisfies the property of absorbing all the radiation that falls on its surface and emits at a constant temperature is considered nearly an ideal black-body. In contrast, the solar thermal collector, used on the roofs of the houses for hot water, is not a black body because it reflects part of the radiation, even if to at a first sight it appears black.

The experimental work carried out at the end of the XIX century found the spectral distributions (radiance[8] as a function of wavelength) and precise bell-shaped curves that constituted a true puzzle for all scientists who tried to explain it (see Figure 3).

Two formulas had been found instead of one that explained the dependency of the radiating energy from the wavelength on all the spectrum. Wien (1893), a physicist, with his law succeeded in explaining the displacement towards the left for short wavelengths, while for Rayleigh-Jeans the displacement was to the right in the case of longer wavelengths.

The physicists have two characteristics: they do not tolerate large gaps between experimental data and those anticipated theoretically, apart from instrumental errors; they will try to reduce the number of laws in order to obtain a unique pattern for physical phenomena.

The first attempts see Planck searching for the unified spectrum law on the basis of the wave model that much satisfaction had given to its estimators, but without success. At this point Planck assumes the existence of a lot of oscillators distributed on wall cavities in a situation of temperature equilibrium

With this hypothesis Planck, in 1899, gains a relation between the charged oscillator medium energy $\overline{E}_\nu$ of determined frequency in equilibrium with a thermal radiation, and the density radiation energy $\rho\nu$ at the same frequency: $\overline{E}_\nu = c^3/(8\pi\nu^2)\ \rho_\nu$.

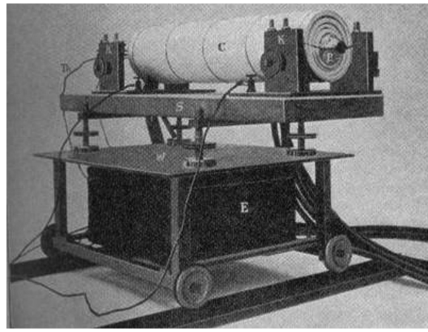

Figure 1. The apparatus for black body radiation measurements (Clayton Gearthart Black *Body Radiation* article in the publication by Renn J. (Ed) *Albert Einstein chief engineer of the universe – one hundred authors for Einstein*. Berlin: Wiley-VCH, Weinheim and Max Planck Institute of the History of Science, Berlin 2005).

Along this way we get to the law of Rayleigh-Jeans that calculates the density of energy of the black body radiation spectrum. This latter one is written: $\rho_\nu = (8\pi\nu^2/c^3)$ kT. But the law of Rayleigh-Jeans involves, for great values of frequency and small values of wavelength, clamorous deviations in respect to experimental data, just for that field of values where the Wien's formula fitted experimental data. In order to prevent this "catastrophe" [9] foreseen from the formula of Rayleigh-Jeans, Planck makes a decision that defines "deprived of hope" but that will be recognized subsequently as the first brick of quantum physics.

In a communication addressed to the Berlin Physical Society on December 14, 1900 in Berlin he claims that the oscillators in thermal equilibrium with radiation emit and absorb a

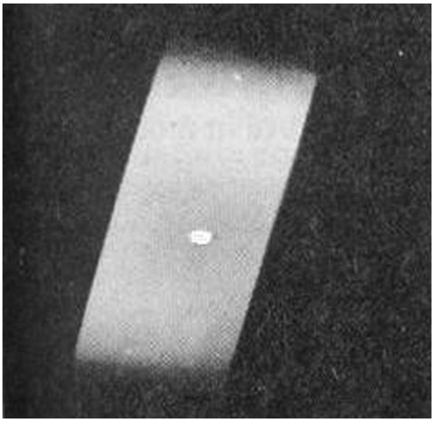

Figure 2. An incandescent tungsten tube with a little hole in the wall. The radiation spreading out of the hole is a *black* cavity radiation (from the chapter *Luce e fisica quantistica*. In Halliday D. and Resnick R. (Eds) *Fondamenti di Fisica 3*. Bologna: Zanichelli, 1996).

"quantum" of energy. In order to obtain a unique formula he employs the same Boltzmann mathematical tool he uses to compute the microstates distribution of gas molecules at a constant temperature. Instead of molecules he considers oscillators distributed on hollow walls in constant interaction with radiation.

Planck computes microstate numbers by dividing total energy states in a finite number of identical quantities; he counts in how many ways the total energy of the state is distributed in a finite number of identical quantities, and in how many ways is possible to distribute these elements of energy between the oscillators. He supposes a quantum energy amount equal to $E = h\nu$ [10] and consequently the radiation density is estimated with the formula:

$$\rho\nu = \alpha\nu^3/(\exp(\beta\nu/T)-1),$$

where $\beta = h / k = 4,866 \cdot 10^{-11}$ s K, $\alpha = 6,10 \cdot 10^{-56}$ W m^{-3} s^3.

This expression is the famous Planck law or formula that fits all radiation spectra.

The introduction of an amount of energy is considered by Planck a mere mathematical artifice, a simple trick, convinced that the nature "non facit saltus".

It is time now to put Boltzmann and his procedure on the stage. Boltzmann introduces the distribu-

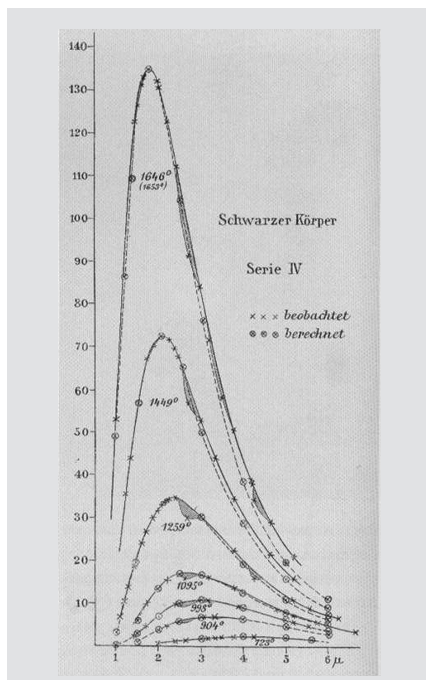

Figure 3. The graphic of black body radiation for a range of temperatures, from the data of Otto Lummer (1800-1925) and Ernest Pringsheim (1859-1917) published in 1899. The solid curve represents the data, and the dashed curve was calculated from Wien's law (see references above).

tion statistics of Maxwell in physics of gases. He considers first a gas in an isolated environment formed by molecules all indistinguishable and free to move without any interactions thought as a microstate system that dynamically and spontaneously is distributed in the space conceived divided into many cells. He demonstrates mathematically that microstates evolve towards a more probable state. In Boltzmann's interpretation the molecules of a gas evolve dynamically and spontaneously in a space thought to be divided into many cells to give a maximum distribution probability[11].

This quantity that dynamically becomes larger and larger is called by Boltzmann "entropy" because it answers to the same properties of its discoverer, the physicist Clausius (1865). According to Clausius entropy is a state function that collects macroscopic variables that in the irreversible processes evolve deterministically towards higher and higher values. Mathematically this means that the trajectory in the space phase is univocally determined. Instead for Boltzmann entropy is associated with a disordered motion of molecules and the evolution of the state that is constituted by many combinations of microstates is not described as a unique state phase trajectory but there are likely many others. The probability that in the irreversible processes entropy increases is much higher but not sure.

At this point Einstein takes the "jack" in hand.

Short abstract of the heuristic viewpoint on the emission and transformation of light. We had left Einstein after having taken from his paper a sibylline statement that we rewrite because it is the key to closing the circle of the covered cognitive complex that opens the way to conceiving quantized radiation: "In the event of the 'radiation of black body', ρ is a function of υ such that the entropy is maximum for an assigned value of the energy". He links the radiation of black body to the entropy, but why does he take this step?

From the beginning of his paper Einstein makes us understand he wants to follow the tracks of Maxwell. As Maxwell at first had written the equations of the electromagnetic field inclining towards analogies between mechanical system and the electrical one, also Einstein follows an analogical idea that encircles a comparison between electromagnetic radiation and a gas of molecules. For this reason, we believe, he defines his research as an heuristic work.

From the first steps Einstein shows that he has in his mind Lorentz electron theory and he totally agrees with Boltzmann choice to use mathematical statistical instrument to explain heat, an hypothesis that involves the consequence that all thermodynamics can be explained on a base of atomic theories. Not only, he literally takes "seriously" the formula that alloys the entropy S to the statistics quantity W that measure the number of possibilities to realise a macroscopic state[12].

This awareness of taking the

quantity W as a physical quantity, representative of microstates distribution state of real molecules, is written in his next paper on "brownian motion". The demonstrations in a "brownian" work that "statistical average displacements" can be foreseen on the basis of the atomic hypothesis of matter, is transferable to radiation that obeys the same statistical laws.

In contrast to Planck who considers the quantum distribution W and then computes S not considering quantum energy "corpuscles" a real physical quantities, Einstein considers the entropy S of the radiation and then he calculates the time distribution W confined in the cavity. Here then we have all the elements for understanding why he considers the maximum entropy cavity radiation. Einstein utilizes methods close to Boltzmann's but inclined towards radiation instead of gas. It introduces the notion of "natural radiation" analogous to the definition given by Boltzmann for "molecular chaos", that is maximum disorder of the distribution of radiation. In fact in Boltzmann's mechanical statistics entropy has an informational value and therefore it is associated with the disorder that quantitatively corresponds to the maximum number of microstate distribution at a certain temperature of the gas (radiation).

Initially, therefore, Einstein studies the entropy of a gas diluted with a variety of molecules at a fixed temperature. The addition of radiation, that he considers monochromatic for simplicity's sake, will reach a situation comparable with that one of the gas confined within the walls of a cavity (cavity radiation).

He starts from the Wien formula, that is in agreement with the black body spectrum for small wavelengths, and demonstrates a statistical link between the variation of entropy S – So of n molecules of a gas closed between the walls of a container at a fixed temperature and the variation of volume V from Vo.

He wondered: "how large is the probability value that at an arbitrary moment all n points moving independently one from another in a given volume Vo are (accidentally) in the volume V? One can clearly write for this probability, which is a "statistical probability", $W = (V/Vo)^n$".

Taking the formula of Boltzmann as a model, a little later he writes:

$$S - So = k \ln (V/Vo)^n.$$

It is important to emphasise that the analogous formula of Boltzmann establishes that the movement of mono variety molecules is completely random, that is the evolution of the states is not determined by the previous configurations of the states of molecules. In other words the system evolves in an accidental way which is unlikely to happen in the systems in which the memory of the previous states determines the successive ones. And this is, luckily, also a peculiar characteristic of electromagnetic radiation.

Einstein looks into the possibility of exploring a new road. He seems to say to us: "If the quantity W used in the formula of Boltzmann represents a real particle function, is it reasonable to suppose that also monochromatic radiation at constant temperature (cavity radiation) can be represented by an 'n' number of 'corpuscles'?". He calculates that it is the right way but at the same time it involves an extension of the hypothesis formulated by Planck on the "quantum" energy, that well fitted the black body radiation spectrum at all wavelengths; he then writes the formula in this way:

$$S - So = k \ln (V/Vo)^{E/h\nu}$$

and he concludes: "if monochromatic radiation (of sufficiently low density) acts, as far as the volume-dependence of its entropy is concerned, as a discontinuous medium consisting of energy quanta of magnitude $R\beta\nu/N$, it is plausible to investigate whether the laws on creation and transformation of light are also such as if light consisted of such energy quanta"[13].

It is very important to consider that Einstein doesn't consider this a conclusion. He is a physicist and every theory must be tested experimentally. The last step, in fact, is to explain some crucial experiments that the classical electromagnetic wave theory didn't. This is a very important step in physics where creativity and ingenious ideas and theories have to match experimental data. Without this successful "commitment" ideas and theories remain in cold storage or are considered only fanciful.

In particular in chapter 8 he tests the theory on the photoelectric effect and finds that the experimental data are closely related to those calculated with the support of the quantum theory.

It's easy nowadays to mention the appendix of mathematical physics on the photoelectric effect as the victorious fulfilment of Einstein's path. But this was not recognized suddenly, because for a long time alternative interpretations were attempted to explain the photoelectric effect. It can be said that the quantum energy experimental confirmations took place subsequently, above all with Einstein's work on specific heat and the large number of tests that were carried out until 1916, the year in which A.H. Compton set up the crucial experiment on X ray diffraction about which nearly all physicists reached agreement.

Conclusions. At the beginning of these 'didactical and historical considerations' we wondered: "has Einstein truly been that genius that is dulled by the null in the history of the humanity, and from null discovers wonderful laws until that time ignored by all?". If we count the number of times in which Einstein cites the "giants" and the other "minors" in his article of 1905 we can list them in the following decreasing order: Wien (8), Maxwell (6), Boltzmann (6), Lenard (5), Planck (5), Stokes (4), theory of the electron (Lorentz) (1), Drude (1), Stark (1).

Then to conclude we feel like saying that scientific enterprises, discoveries, original ideas and ingenious mature in a determined historical context, inside scientific communities that carry out research in a determined direction. In our opinion, the genius arose in history as an unexpected eruption from an earth in ebullition, like a mother giving birth under pain, rather than a brilliant meteor that in a moonless night spreads light over the world.

There are 11 years between quantum energy experimental confirmation and 1905 and 16 before the official acknowledgment of the scientific community awarding Nobel prize to a man that first gave a convincing explanation. So, at the end of our path we wonder: "Do we become a genius or are we a genius from our birth?".

We think that Einstein's discoveries however could have been made by others, but this conviction at the same time does not remove from Einstein the acknowledgement of a special "ingeniousness" that can be summarised in a question: "How can a 26 year old young man write, in his free time, five works that rebuilt the bases of physics and that after one hundred years still make people discuss with amazement?".

[1] CLIL = Content and Language Integrated Learning is a plurilinguistic experimental project in High School to promote teaching in different languages.

[2] SSTeF = Societât Sientifiche e Tecnologjiche Furlane.

[3] We refer to ITI "A. Malignani" drive-language teaching experiences from 2003. The didactical modules were produced from IRRE del FVG and successively from USR del FVG under Rosalba Perini and Luigi Torchio supervision.

[4] Italian correspondences are exposed in the Museo per la Storia dell'Università di Pavia.

[5] The experiments are commented in *Les Météores* (1644) and *Optiks* (1706) respectively.

[6] Newton theory is more complex and it cannot be reduced entirely to a wave model; in his theory he also compares wave concepts as useful mathematical tools to make predictions.

[7] A picture of an entrapping radiation can emerge if we imagine a *bombus terrestri* fortuitously crossing through a slot of a glass window; it flies hitting the transparent glass for a long time before finding out the slot to go away. If in a very large room there is a large amount of *bombus*, more than the a few enter through a slot, we will find an equilibrium between the number of "input bombus" and "output bombus".

[8] The radiance unit measurement is $Wm^{-2} \cdot 10^{-6}$ m.

[9] Historians have called this result: "ultra violet catastrophe".

[10] $h = 6, 67\ 10^{-34}$ j s.

[11] It is for the same reason that the smoke puffed from the mouth of a smoker spreads till filling uniformly a room.

[12] The famous formula S = k lnW where $k = 1, 38\ 10^{-23}\ jK^{-1}$ Boltzmann costant.

[13] The ratio N / R ß is the "h" Planck constant with N Avogadro's number or Lodschmit's number, R gas constant and $\beta = 4, 866\ 10^{-11}$.

Einstein' 1905 articles list/ I articui di Eistein dal 1905

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