

A Descoberta dos Raios-X: um Provável Caso de Observação de Segunda Ordem

The Discovery of X-Rays: a Probable Case of Second Order Observation

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Abstract

The discovery of x-rays, one of the most beautiful experiments ever carried out, generates numerous controversies and these, in turn, can trigger a series of counterproductive information regarding not only the History of Science but also the teaching activity. The aim of this article is to resolve these controversies concerning what occurred and highlight the important role of the German physicist Wilhelm Conrad Röntgen, highlighting not only his genius but, especially in this case in particular, his condition of second-order observer. It is not uncommon to find information in various media referring to this discovery under the claim that it was the result of a fortuitous event, and this denotes a profound lack of knowledge about the facts or a disrespect for the renowned discoverer. Such allegations about the event depreciate the extraordinary discovery that impacts humanity, from the deed to the present. Thus, through a brief historical reconstruction, it was tried to present here what had happened judiciously. With this respect, the brilliant scientist is given the status of a second-rate observer, from the philosophical point of view. This condition resonates with the diachronic aspect of the History of Science, according to the perspective presented here, and it is also supported by the time taken by the discoverer from the beginning of his research until the end of it.

Keywords: X-Ray. Second-Order Observer. History of Science.

Resumo

O descobrimento dos raios-x, um dos mais belos experimentos já realizados, gera inúmeras controvérsias e essas, por sua vez, podem desencadear uma série de informações contraproducentes no tangente não só a História da Ciência como também à atividade de ensino. O presente artigo tem como objetivo dirimir tais polêmicas com respeito ao ocorrido e destacar o importante papel do físico alemão Wilhelm Conrad Röntgen, destacando não só sua genialidade, mas sobretudo, neste caso em particular, a sua condição de observador de segunda ordem. Não é raro encontrar em diversos meios de comunicação informações com respeito a referida descoberta sob a alegação de que a mesma fora fruto de um caso fortuito e isso denota profundo desconhecimento sobre os fatos, ou então, desrespeito com o renomado descobridor. Tais alegações sobre o sucedido depreciam a descoberta extraordinária que impacta a humanidade, desde o feito até a atualidade. Assim, através de breve reconstrução histórica, buscou-se aqui apresentar o ocorrido criteriosamente. Com este respeito passa-se a atribuir ao brilhante cientista a condição de observador de segunda ordem, do ponto de vista filosófico. Tal condição encontra ressonância no aspecto diacrônico da História da Ciência, segundo a perspectiva aqui apresentada e está amparada, também, pelo tempo empreendido pelo descobridor desde o início de sua pesquisa até a finalização da mesma.

Palavras-chave: Raios-x. Observador de Segunda Ordem. História da Ciência.

1 Introduction

This article has as motto the unusual discovery of the x-rays. Unusual in the sense of singular and not due to serendipity¹, for example. The non-occurrence of serendipity is based not only on the discoverer's reputation, Wilhelm Conrad Röntgen, but mainly on the historical accounts of the discovery. "It is often said that this discovery was made by chance and Röntgen's contribution is commonly minimized - as if he had done nothing but realized the existence of a new kind of radiation" (MARTINS, 1998, p.373).

The previous paragraph may rather provide a first idea that the discoverer, in addition to his undisputed abilities as a scientist, has properly used crucial information for the

discovery, however, the way he did it, as this article seeks to emphasize, is about an evident tool called second-order observation. This procedure is described here from the perspective of sociologist Nicklas Luhmann. Such a quotation is important, since the subject is not treated solely and exclusively by Luhmann, but also by other authors, however, here it is portrayed under his interpretation.

In order to clarify it even further, for Gil (2007), for example, "the experimental research consists of determining a study object, selecting the variables which would be able to influence him, defining the forms of control and observation of the effects that the variable produces on the object". From this, one can make the comparison exercise to the Röntgen

1 Serendipity: term idealized by Lord Horace Walpole, which describes something discovered, purely and simply, by luck;

achievement. With the object of determined study and with some variables that could cause some influence, as we will see in the course of this text, already established (not all of them), the scientist was left with the exhaustive work of defining forms of control and meticulous observation about the experiment itself. That is, some important steps and good time were saved by admitting the condition of second-order observer to the notorious German physicist.

The X-rays discovered by Röntgen, for example, play a fundamental role in the development of a series of discoveries revealed over time, as a kind of foundation for new scientific guidelines (GONÇALVES; PINHEIRO, 2017)

Therefore, it is essential to contextualize not only the period and the studies carried out about what we now call x-rays, but also, to make reference to some of the studies previously undertaken in the area.

This refers to such names as: Michael Faraday (1791-1862), Julius Plücker (1801-1868), William Crookes (1832-1919), Eugen Goldstein (1850-1931), Joseph John Thompson (1856-1940), Heinrich Hertz 1857-1894), and especially Philipp Lenard (1862-1947).

Röntgen was conducting studies in other fields of Physics. His main purpose was not to investigate the cathode rays. It is obvious here that, most likely, it was the circumstances that led him on this path, since Röntgen was occupying the directorship of a large European university (Director of the Institute of Physics of the University of Würzburg) and, because of that, it was natural that at some point, he could be interested in the most prominent theme in the scientific community of that continent at that time.

2 Development

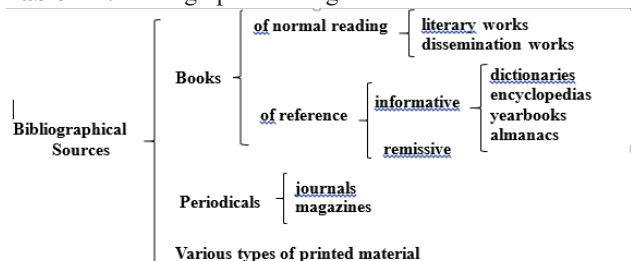
2.1 Methodology

The present article is structured based on already elaborated materials, which configures it as of bibliographic nature.

This configuration is established from the critical reading of scientific articles published in indexed journals, such as: Gonçalves & Pinheiro (2017), Martins (1998), Röntgen (1896) and Santos (1995), as well as texts available on the web, Assmus (1995) and also books, Bassalo (2000), Gil (2007) and Luhmann (1993).

Gil (2007) categorizes bibliographic research according to the following table:

Table 1 - : Bibliographical categories.



Source: Adapted from Gil (2007)

In accordance with the established, this article is duly constituted of several categories of bibliographical sources demonstrated by Table 1.

The respective bibliography includes books of reference, current reading and also periodical publications.

The choice for this type of research consists, fundamentally, of dealing with issues of historical nature, in addition to other prerogatives, such as, for example, the treatment of a range of phenomena involved in the text whose origins come from the most diversified areas of knowledge: Physics, History of Science, Philosophy.

Also, in Gil (2007), “Literature research is also indispensable in historical studies. In many situations, there is no other way of knowing the facts of the past if not based on bibliographic data “.

In general, what is sought in this article is to grant Röntgen the status of observer of the second order through a historical reconstruction, from a critical reading of scientific articles and books, in a rational and systematic way whose actions scrutinized in the course of the process were planned effectively.

2.2 Discussion

2.2.1 Previous studies

Once mentioned some names, it is important to go through their achievements in the respective area of interest of this work and, with that, to describe the path that precedes the success of Röntgen.

Faraday, for example, has a fundamental importance in the development of these studies, since he is considered one of the greatest experimenters in the history of science and had as tutor Humphry Davy and under his tutelage carried out important tests on gas diffusion, electric discharges in rarefied gases, among others. Despite being in one of the most well-equipped laboratories, Davy’s, Faraday could not go much further regarding the cathode rays, because there was no way to produce good quality vacuum at the time.

Julius Plücker, on the other hand, devoted part of his academic life to rarefied gas spectrometry, and thereby increased procedures about the deviation of cathode rays that crossed magnetic fields, as Bassalo (2000, p. 479) states:

Between 1858 and 1859, the German physicist and mathematician Julius Plucker conducted a series of experiments, published in 1858 in the *Annalen der Physik und Chemie* 103 (p.81, 151), 104 (p.131, 622), 105 (p. 67), and in 1859, in volume 107 (p.77), about the electric discharge in gases. In these experiments, made with rarefied pipes constructed by his professor, the German physicist Johann Heinrich Wilhelm Geissler (1814-1879), in 1855, Plücker observed that “rays” originating from the cathode of the tube of Geissler (name coined by him) were diverted when in the presence of a magnetic field.

Here, it is necessary to present a significant aspect concerning the subject. For some years, the cathode rays were

interpreted in antagonistic ways. For the German physicist Goldstein, the rays were waves in the ether, but for Crookes they were charged molecules. Another historical fact should be emphasized here. According to Bassalo (2000, p.479):

In 1876, the German physicist Eugen Goldstein published a work in the *Monatsberichte Akademie der Wissenschaften zu Berlin* (p. 279), in which he called the cathode rays (Kathodenstrahlen) the emanations from cathode of a vacuum tube which had been constructed by the English physicist William Crookes, in 1875.

In 1892, the German physicist Henry Rudolf Hertz published an article in *Annalen der Physik* 45 (p. 28), in which he presented the results of his experiments with cathode rays and in which he observed that they passed through thin metal blades. Because of this, he concluded that such “rays” were not composed of matter and therefore could only be waves.

The path seems to be unraveled when J. J. Thomson, a noted British physicist, realizes that cathode rays, in addition of being deflected by a magnet, also suffered when subjected to electric fields. With this, it is assumed that the cathode rays were, in fact, electrons. Thomson, inclusive, was awarded in 1906 (Nobel Prize of Physics) due to studies on electrical discharge in gases.

Finally, at least in this work, a paradigmatic character from the contextualized point of view. An active researcher in this area, the Hungarian-German physicist Philipp Eduard Anton von Lenard, a student of Hertz, is an important figure in the sense of discovery. Seeking to repair a misunderstanding, Lenard was a brilliant researcher and did not “stumble” in the rays as some insist. Such redress, if necessary, is based on the researcher’s career. Among other awards, Lenard was awarded the Nobel Prize for Physics in 1905. “[...] for his pioneering work with the cathode rays” (BASSALO, 2000, p.478).

In an article published in the *Annalen der Physik* in 1894, Lenard already makes very important considerations in this regard, such as: the sensitization of photographic plates exposed to lightning and the capacity of lightning to discharge a previously electrically charged aluminum disc.

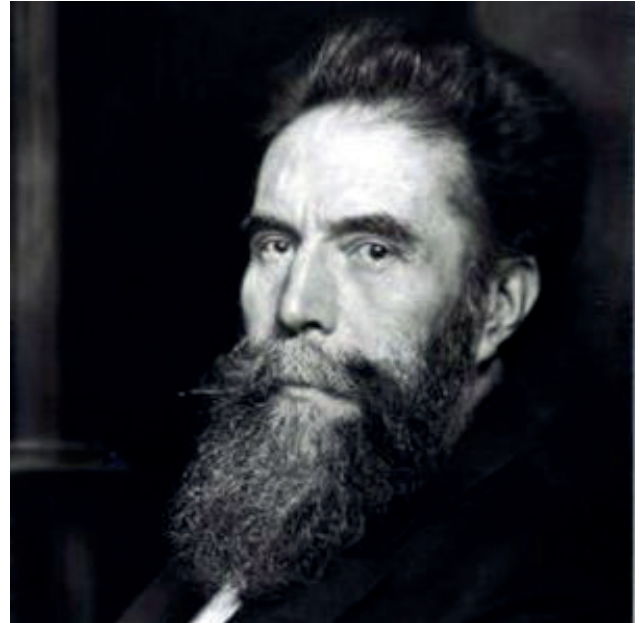
It is substantial to consider that these are just a few of the numerous studies that have had a profound impact on sciences at the time, including intrinsic relevance to further research. Such a weighting is carried out with the purpose of clarifying that this article does not intend to carefully deal with any historical or theoretical framework about X-rays, but to raise the condition of second-order observer of the noble discoverer Wilhelm Conrad Röntgen.

2.2.2 Wilhelm Conrad Röntgen and the X Rays

Röntgen, the son of a German merchant and a Dutch mother, was born in the town of Lennep on 27 March 1845. He lived for a few years in Holland, more precisely in Appeldoorn. In 1862, he entered the Technical School of Utrecht and in 1866 he joined the Polytechnic School of Zurich, Switzerland.

However, only in 1876 Röntgen really became a Professor of Physics at the University of Strasbourg and in 1888 he achieved the position of Professor and Director of the Institute of Physics of the University of Würzburg (Bayerische Julius-Maximilians-Universität Würzburg).

Figure 1 - Röntgen¹



Source: www.biography.com

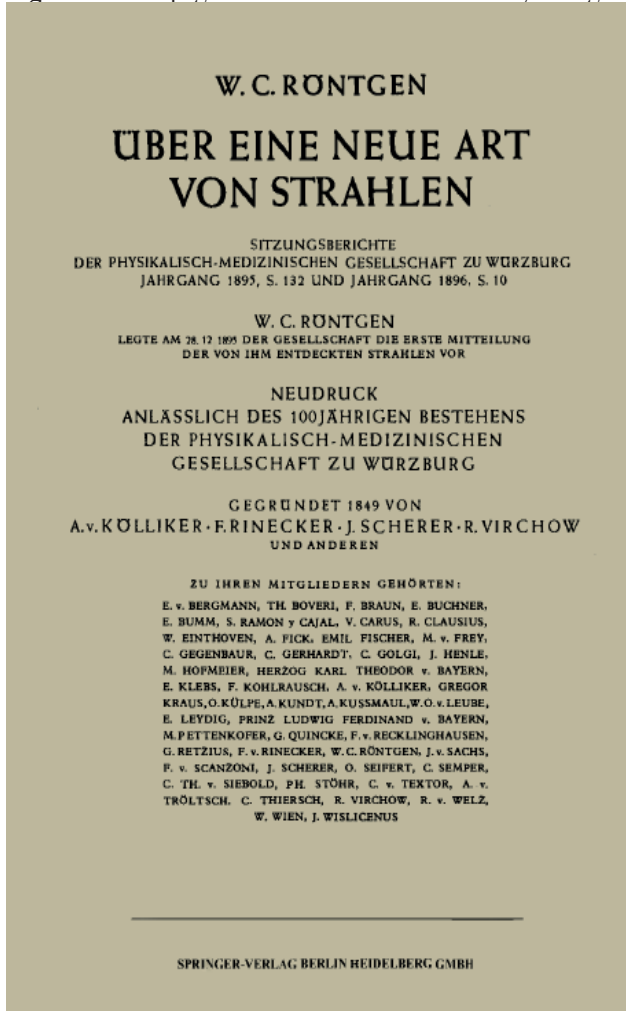
About the discovery itself, the scientist seemed to see over the shoulders of every scientific community that was concerned with investigating the cathode rays coming from such tubes.

In 1901, the Nobel Prize in Physics was awarded to the German Wilhelm Conrad Röntgen for his discovery of x-rays. On November 8, 1895, Röntgen studied the effects of cathode rays produced between electrodes subjected to electrical potential difference in an evacuated glass tube. However, having covered this tube with dark paper, he observed that a barium platinum-cyanide screen placed a certain distance from it would fluoresce as long as the cathode rays were fired. In this way, Röntgen deduced that some invisible radiation - which he named x-rays - had crossed the dark paper and caused the fluorescence on the screen. This discovery was communicated to him at a meeting of the Würzburg Physico-Medical Society on December 28th, 1895, and published in the *Sitzungsberichte der Würzburger Physikalischen-Medicinischen Gesellschaft* 137 (BASSALO, 2000, p. 476).

Several changes occurred. The tubes were no longer the same, which will be reported soon, and the quality of the equipment was superior to that used by Faraday, for example. However, Röntgen’s wit and his accuracy in writing made him one of the greatest scientists of all time.

2 Available in: <http://www.biography.com/people/wilhelm-conrad-röntgen-39707>.

Figure 2 - First page of the communication made by Röntgen.



Source: Röntgen (1896)

In this presentation (Figure 2), Röntgen details in 21 topics all the details of his discovery.

In the order in which they appear in communications, these properties are as follows. Firstly, the rays can be detected by scintillations on a phosphorescent screen, or from prints on a photographic plate. Unlike cathode rays, X-rays can be observed even when the screen is placed at a distance of about two meters from the vacuum tube (cathode rays do not exceed more than eight centimeters in the air). Röntgen tests the transparency of an enormous amount of materials, verifying that two properties are important: the density of the material and the thickness; the denser and thicker, the less transparent. After testing for transparency, Röntgen investigates the effects of refraction and reflection. He does not observe either, although he has been in doubt as to the reflection. He tries to deflect the x-rays with the aid of a magnetic field, but can't do it, and here he establishes one of the fundamental differences, from the experimental point of view, between the x-rays and the cathode rays, since these last ones are easily deflected by a magnetic field (SANTOS, 1995, p. 30).

Still, according to Santos (1995, p.31), other differences between his work (and apparatus!) can be identified in the course of his dissertation.

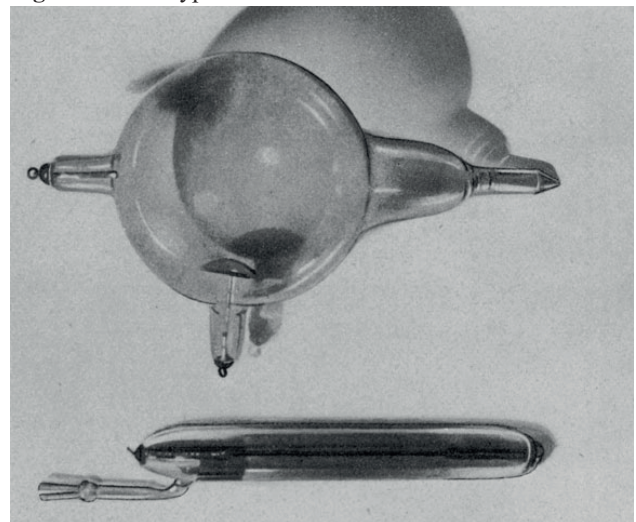
In topic 12 he discusses one of the most fundamental

questions for the identification of the x-rays. He concludes that these rays are produced by the cathode rays in the glass wall of the discharge tube! He then informs that he has observed X-rays produced by the cathode ray shock on an aluminum plate, and promises to test other materials. A year later, on December 17, 1896, the British physicist Sir George Stokes demonstrated that X-rays are produced by the deceleration of charged particles, a phenomenon that occurs when, for example, high-energy electrons penetrate a heavy material! Or, in the language of the time, when the cathode rays penetrate a heavy material!

And finally: "In the final topics, 19, 20 and 21, he discusses practical questions: induction coil operation, vacuum maintenance and difference between aluminum and platinum, regarding the intensity of the beam produced" (SANTOS, 1995, p. 31).

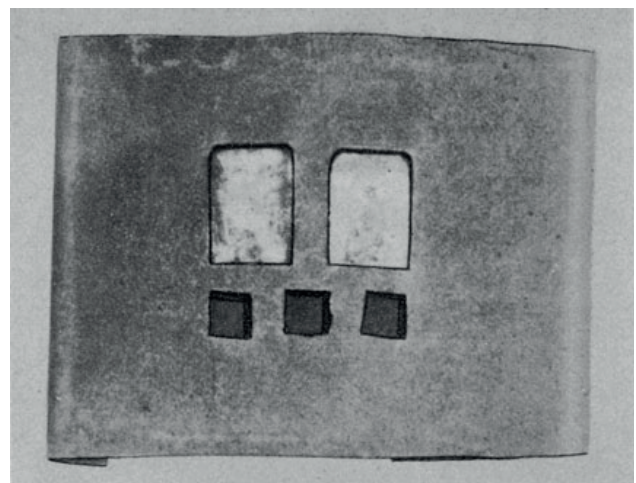
As a curiosity, there are some official photos (Figure 3, 4 and 5) of the apparatus that is now located at the Institute of Physics of the University of Würzburg.

Figure 3 - Two types of tubes used at the time:



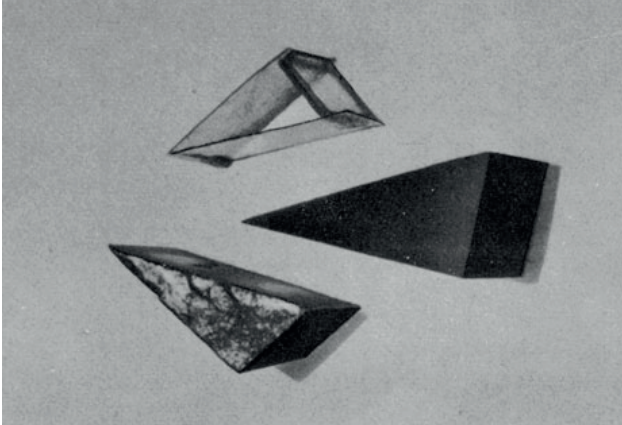
Source: Röntgen (1896)

Figure 4 - Lead sheets with openings made from various metals:



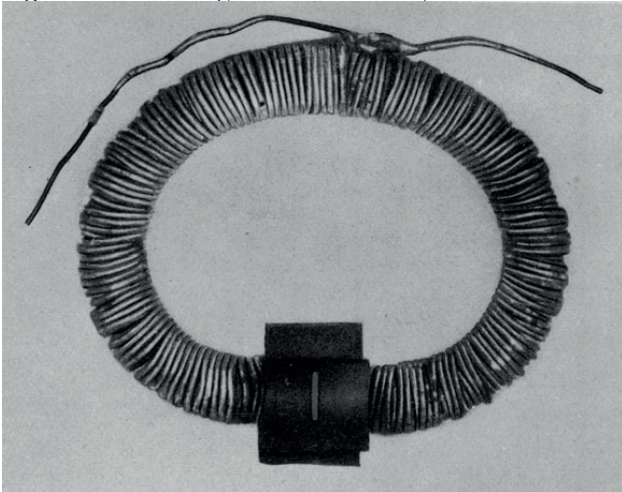
Source: Röntgen (1896)

Figure 5 - Prisms made of hard rubber and aluminum and hollow prism of mica were placed on the horizontal lead plate:



Source: Röntgen (1896)

Figure 6 - Electromagnet used for the rays deflection:



Source: Röntgen (1896)

2.2.1 Second-Order Observation

First of all, the German sociologist Nicklas Luhmann (1927-1998) needs to be presented here. He was an academic of Law at the University of Freiburg between 1946 and 1949, but it was at Harvard in 1961 that he changed the course of his history. That year, Luhmann would study sociology with the most renowned researcher in this area, at the time, Talcott Parsons.

Among his main works, it is possible to highlight: Introduction to Systems Theory; The Reality of the Mass Media; Legitimation Through Procedure; A Sociological Theory of Law; Theory of Society and others. The present work is focused, basically, on the work titled Risk: A Sociological Theory (1993). More specifically, in the chapter XII called Second-Order Observation.

Here we present some of the arguments in the respective chapter, on which the idea of Röntgen's second-order observer status is based.

As a presentation, and in order to better situate the reader regarding this work, the aforementioned work, Risk: A Sociological Theory, is composed of twelve chapters and, in

great part, it refers to the relationship between science and risk.

The second-order observation condition must, logically, presuppose the condition of a first-order observation. In a brief relation, one can clarify risk according to the form of observation.

However, we approach the concept, we can speak of risk only if we presuppose that the person who perceives a risk and eventually assumes it draws certain distinctions, namely the distinction between good and bad results; advantages and disadvantages; profits and losses; and the distinction between the probability and improbability of their occurrence. Anyone who behaves riskily - who for example, takes risks in traffic or plays with guns - may do so as first-order observer. But as soon as he considers whether to take a risk, he observes himself from the position of a second-order observer; for only then do the distinctions typical for risk constitute the point of departure for the operation, taking the other side into account and not only reporting objects (LUHMANN, 1993, p. 219)

There are other ways of interpreting second-order observation, or rather, for each of the various fields of action, there are several compelling explanations.

Moreover, the distinction between decision makers and affected parties also relates to the level of second-order observation. The decision makers observe that they are being observed. Each of them is explained in terms of the presumed characteristics of those he happens to be observing. This serves to establish oppositions at the level of first-order observation - the 'capitalists', the 'greens', etc. But the occasion for opposition arises not from the facts but from the observation modes of the other side; this presupposes second-order observation. (LUHMANN, 1993, p.220).

This problem recurs at more concrete levels. It is not only that empirical content has to be logically and theoretically reconstructed, but also that practical orientation is required. Where experts are consulted - a much discussed and politically controversial proceeding - it is almost self-evidently a question of whether the experts as an authority on (observer of) science pronounces his support for or opposition to a project, or how he will answer some material question or other. Already at the stage of selecting experts, assumptions will be made about the sort of expert opinion to be anticipated. One does not have to be an expert oneself, but one must be able to assess the expert as an observer of his field. And this is impossible without a modicum of knowledge in the matter. Even if it is a question of turning technological risk into a political topic, a need for decision making is generated that can be observed in different ways within the political system itself. The supporters of the project and its opponents will differ in the way they see it. Each will observe or have the others observe the material problem itself, for example, the safety techniques in risky production processes; and will at the same time form an opinion on the quite different question of how the political chances stand and how different varieties of politicians will judge the matter - politicians who are themselves not free in their assessment, but under observation. For this reason, they do not act arbitrarily, and can consequently be observed. Whoever is unable to perform in this second-order observation arena will soon be able to

observe himself as someone who is no longer admitted to join the game. (LUHMANN, 1993, p. 220-221).

Röntgen seems to have taken some crucial steps on the way to discovering the x-rays, such as looking closely at the experiments performed by other scientists. It is at this point that the present text is supported and finds support in the sense of its presentation from the perspective that the discoverer, astute researcher, has used the condition of second-order observer, as stated in the following paragraph.

“I was interested long ago in the problem of cathode ray in vacuum tubes, studied by Hertz and Lenard” (MARTINS, 1998, p. 375).

The testimony transcribed in the previous paragraph was given by the discoverer himself to the american reporter Henry Dam and it describes well the condition lived by Röntgen at the time. It can be seen that Röntgen was concerned with previous studies, especially the studies carried out by Hertz and Lenard.

Thus, there are sufficient elements to recognize that conjectures presented in previous studies were very valuable in the process of the x-rays discovery and not only that, they have put Röntgen in a privileged situation, since he used many hypotheses raised in the early days of the studies and which were already refuted at that time, as well as other assumptions which, although well articulated, were suddenly dismissed by the German physicist. A good example of such statements is portrayed by the excessive dedication of most scientists concerning what occurred within the tube of rays to the detriment of what occurred outside it. In order to clarify the issues, Lenard was one of the forerunners about concerning himself with what happened on the outside of the tube of rays, but he did not look beyond the ethereal nature of these rays, in clear contrast to the British scientists led, then, by JJ Thomson.

We must above all remember that at the level of second-order observation hierarchy formation is no longer possible, and that hierarchies switching to second-order observation, for example, in the relations between subordinates and leadership, are thereby relativized. This cancels the possibility of forming an opinion about a system by observing the way in which the top echelon observes. Other, heterarchically coordinated reductions in complexity are necessary instead. Science, for example, has its publications and a highly selective reviewing system. One observes colleagues not as they observe but via their publications. (LUHMANN, 1993, p.227).

The publications made about the experiments also lead to the understanding that the discoverer enjoyed his condition as a second-order observer, especially in relation to the Hertz and Lenard essays.

As a characteristic of the new physics: the cathode ray physics, the x-rays, the alpha rays, the beta rays, the gamma

rays and the N-rays - the nature of the cathode rays was disputed in Europe, for the British it was a stream of particles, as for those of the continent, they preferred to think of them as a kind of disturbance of the ether. A strong reason to believe that cathode rays were particles was the observation that they would not pass through matter that was transparent to ultraviolet light. When Heinrich Hertz discovered that he could pass the rays through metal paper, a fellow German scientist, Philip Lenard, began to study them more carefully. Lenard designed a tube with a thin aluminum window through which the rays could emerge, and he measured how far they could travel and still induce fluorescence. Defined in this way, the range of cathode rays was six to eight centimeters. Lenard's experiments inspired Röntgen to wonder whether the rays in an attenuated form would actually travel further, and he planned experiments to see if a sensitive electroscope could measure a discharge four times the distance Lenard had identified (ASSMUS 1995, p.12).

The conditions presented in the above paragraph can also be considered from a privileged positioning of the discoverer. In addition to the time saved by him, it is still necessary to take into account premises and hypotheses, refuted or corroborated in the course of the research, which would require exhaustive tests with the respective experiment.

From this, as a meticulous experimenter, Röntgen seeks to understand what has occurred beyond the cathode ray tube. To do so, he studies in depth all the characteristics of these rays, as for example, the direct direction of the same ones. Another important factor was the investigation of the possibility of refracting or reflecting such rays. Thus, one might conclude that it was a new type of ray, distinct from the cathode rays, since the last ones were susceptible to magnetic deflection, as Philipp Lenard had already attested.

3 Conclusion

An important note about the researcher's work is about his working time. Reports admit that the German physicist did not take long to succeed and clarify the phenomena that occurred as a result of his experiment, about eight weeks. Here, also, there are evidences of his comfortable position as a second-order observer based on the very short time demanded for the conclusion of this research. Several steps to the progress of the studies had already been made, and it was up to the astute scientist the discovery.

Röntgen leaves this fertile field of research³ and returns to other topics. Röntgen owned a solid reputation and a respectable image with his peers.

Undoubtedly, the occurrence of the discovery is the result of Wilhelm Conrad Röntgen's sagacity, quirkiness, and high investigative ability and, moreover, it is a typical case of second-order observation regarding what has already been observed by several scientists.

3 Among other contributions, the subject still provided the Nobel Prize for Physics, not only to Röntgen (1901), but also to Lenard (1905), Thomson (1906), Lauer (1914), W.H. Bragg and W.L. Bragg (1915), Barkla (1917) and Siegbahn (1924).

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