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BEFORE *STRUCTURE*. THE RISE OF KUHN'S CONCEPTUAL SCHEME IN *THE COPERNICAN REVOLUTION*

Abstract. Thomas S. Kuhn's intellectual development could be summed up in a two-stage course, first, the transition from physics to the history of science (primarily physics) and then from the history of science to the philosophy of science, a field in which he achieved consecration with *The Structure of Scientific Revolutions* (*SSR)* published in 1962. In the 1950s, before *SSR*, Kuhn dealt with the history of science and, finally, developed a detailed research on the case of the Copernican Revolution, publishing a book with the same name. *The Copernican Revolution. Planetary Astronomy in the Development of Western Thought* (*CR*). My aim in this paper is to argue that in this case study Kuhn identified all those situations that he will later describe in the terms of the *SSR*'s vocabulary, from "paradigm" and "incommensurability", to "normal science" and "scientific revolution." I think that although the terminological options in *CR* differ, such as, for example, the use of the expression "conceptual scheme" for what will later be called "paradigm", a simple conceptual archaeology directs us to claim that *CR* is the immediate predecessor of *SSR.*

Keywords: Thomas S. Kuhn, history of science, Copernican Revolution, scientific revolution, scientific belief, cultural and intellectual contexts

1. The road to the history of sciences

After completing his studies at Harvard University with a Ph.D, in Physics, the young Kuhn continued with several scientific studies to deepen the research in his own field of specialization. The Ph.D. thesis was published

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by Harvard University under the title "The Cohesive Energy of Monovalent Metals as a Function of Their Atomic Quantum Defects" in 1949. Two studies published one year later in *Physical Review*, "A Simplified Method of Computing the Cohesive Energies of Monovalent Metals" and "An Application of the W.K.B. Method to the Cohesive Energy of Monovalent Metals," seemed to announce a researcher devoted to his very narrow field of scientific interest and by no means concerned with the history of science and, even less, with any philosophical aspects. Eventually, the only admissible extensions of the research lead beyond the borders of Physics in the immediate neighbouring in the area of mathematical physics, a fact confirmed by the article "A Convenient General Solution of the Confluent Hypergeometric Equation. Analytic and Numerical Developments", published in *Quarterly of Applied Mathematics* in 1951.

But such an image of his career beginnings become apparent and deceptive since it considers this one-sided interest for professionalization in the academic field of Physics. In fact, Kuhn's first public appearance as an author in the Harvard University environment was the early publication in 1945, in the magazine of the alumni society, of some declared subjective notes regarding the characteristics that education should have in a free society (Kuhn 1945a; 1945b).

The decisive event that directed him towards the history of science happened, as he testifies in the "Preface" to *The Essential Tension* (Kuhn 1977, xi), in 1947 when, as a result of an institutional request, he interrupted his physics studies to prepare a series of lectures on the history of science, especially on the origin of mechanics of the 17th century. These lectures were a kind of introductory science lessons that he gave to students from the humanities field, not interested in a career in science, but whose general culture had to be built up by including some elementary scientific knowledge. The lectures were part of an innovative curriculum designed by James B. Conant, president of Harvard University, who proposed a comprehensive educational model, based on achieving a balance between humanistic culture and scientific training[2]. Conant considers that an intellectual history of science involves placing science in a cultural context, which leads to a new image of science and which allows us to understand that

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2 For details about this project see Swedlow, 2004.

"science has been an enterprise full of mistakes and errors as well as brilliant triumphs; science has been an undertaking carried out by very fallible and often highly emotional human beings; science is but one phase of the Western world which have given us art, literature, and music" (Conant 1995, xviii).

Kuhn later described the consequences of assuming this institutional task which gradually turned itself into an exploratory and formative experience. The course was focused on case studies from the history of science which gave him the opportunity to study ancient scientific texts, including Aristotle's *Physics.* If he was initially disturbed by the Aristotelian theories, so different from those of modern physics, he tried to understand them correctly in their own context and was thus able to find an explanation regarding the acceptance of Aristotelian physics by the ancient thinkers. Kuhn realized that it is a mistake to read the Aristotelian texts from the perspective of Newtonian vocabulary and tried to enter into the conceptual network of Aristotelian way to put the questions and give the answers. He understood the for Aristotle, unlike Newton and his successors, the main subject

> "was change-of-quality in general, including both the fall of a stone and the growth of a child to adulthood. In his physics, the subject that was to become mechanics was at best a still-not-quite-isolable special case. More consequential was my recognition that the permanent ingredients of Aristotle's universe, its ontologically primary and indestructible elements, were not material bodies but rather the qualities which, when imposed on some portion of omnipresent neutral matter, constituted an individual material body or substance. The position itself was, however, a quality in Aristotle's physics, and a body that changed its position therefore remained the same body only in the problematic sense that the child is the individual it becomes. In a universe where qualities were primary, motion was necessarily a change-of-state rather than a state." (Kuhn 1977, xi-xii)

Moreover, as he will mention in the "Preface" to The *Copernican Revolution* when he combined the strictly technical aspects with those of intellectual history, he realized that although "scientific materials are essential, they scarcely begin to function until placed in a historical or philosophical framework where they illuminate the way in which science develops, the nature of science's authority, and the manner in which science affects human life" (Kuhn 1995, ix).

As a result of this teaching activity, Kuhn also reconsidered the priorities of his scientific research and he turned form physics to the history of science, the main themes approached in this context being the theory of matter from the 18th century and then the early history of thermodynamics. He begins to publish a series of short articles and reviews on these topics in the prestigious journal *Isis* edited by the University of Chicago, founded and directed by George Sarton between 1913 and 1952, taken over from 1953 by I. Bernard Cohen, professor of the history of science at Harvard University. *Isis* journal promotes both studies on fundamental theories in the history of science, as well as on applied developments in medicine and technology, or on contextual economic, social and cultural influences. Kuhn first publishes, in 1951 and 1952, several studies and a reply on topics regarding the theory of matter developed by Newton and Boyle. These are: "Newton's 31st Query and the Degradation of Gold" (Kuhn 1951b), "Robert Boyle and Structural Chemistry in the Seventeenth Century" (Kuhn 1952a), "Reply to Marie Boas: Newton and the Theory of Chemical Solution" (Kuhn 1952b), "The Independence of Density and Pore-Size in Newton's Theory of Matter" (Kuhn 1952c). The next two years were intensively used for a historical research of Descartes and Galilei works. Kuhn has published two reviews, one in *Isis* about "*The Scientific Work of René Descartes* (1596-1650), by Joseph F. Scott", and of "*Descartes and the Modern Mind*, by Albert G.A. Balz" (Kuhn 1953a), another in *Science* about "Galileo Galilei: *Dialogue on the Great World Systems*, revised and annotated by Giorgio de Santillana" and of "Galileo Galilei: *Dialogue Concerning the Two Chief World Systems – Ptolemaic and Copernican*, translated by Stillman Drake" (Kuhn 1954b). Kuhn also reads and reviews in *Isis* works on the Cartesian philosophy such as "*New Studies in the Philosophy of Descartes: Descartes as Pioneer and Descartes' Philosophical Writings*, edited by Norman K. Smith," and "*The Method of Descartes: A Study of the Regulae*, by Leslie J. Beck" (Kuhn 1955c). Finally, paying attention to new appearances in the field, Kuhn becomes a critical reader of *Ballistics in the Seventeenth Century: A Study in the*

Relations of Science and War with Reference Principally to England, by A. Rupert Hall (Kuhn 1953a), *The Scientific Adventure: Essays in the History and Philosophy of Science*, by Herbert Dingle (Kuhn 1953c) and *Main Currents of Western Thought: Readings in Western European Intellectual History from the Middle Ages to the Present*, edited by Franklin L. Baumer (Kuhn 1954a), published alternatively in *Isis* and *Speculum*. If the first works of this kind proposed an externalist perspective that considered the relationship between science and technology, the latter two were the expression of the increasing concerns for the intellectual history of science. All these concerns are the evidence of Thomas Kuhn's effort to synchronize with the current state of research in the field of the history of science and to assert himself as a researcher who belongs to this field and is part of this community of researchers.

Some of the case studies on which the series of lectures was based attract his attention by their relevance for a new understanding of the history of science. Kuhn begins to work on the project of a larger research on the Copernican Revolution and is concerned with the beginnings of thermodynamics. On this last topic, he publishes two notes about the so-called "Carnot cycle", "Carnot's Version of Carnot's Cycle" (Kuhn 1955a) and "La Mer's Version of Carnot's Cycle" (Kuhn 1955b). The fact that between 1955 and 1957 he did not publish much anymore, is an indirect proof of directing his efforts towards the completion of the book about the Copernican Revolution. In the same years he is involved in the activity of the Society for the History of Science, founded in 1924 by the same George Sarton, publishing the minutes of the council meetings and one report (Kuhn 1956a; 1956b).

In short, starting from 1947, when he begins to prepare the series of lectures on the history of science and until the publication of the book *The Copernican Revolution. Planetary Astronomy in the Development of Western Thought* in 1957, Thomas Kuhn went through a complete metamorphosis process from a specialist in physics into a historian of science. But even more important is the way in which Kuhn rethinks the traditional history of science as intellectual history.

2. A new approach to the history of science

The history of science was traditionally divided into the external (or externalist) history of science, which implied a historical vision of the facts by correlating the process of science development with the evolution of society, primarily from an economic and technological standpoint, and the internal (or internalist) history of science, which implied a perspective on the history of science as a history of ideas or an intellectual history. This second perspective had gained more prestige and relevance even in the years when the young Kuhn was asked to deal with the history of science in the form of significant case studies. The debate on how the history of science should be done was opened by Sarton with a famous article (Sarton 1916) in which he identifies the dilemma between the prioritization of the external conditions of science development and, respectively, the highlighting of the ideational relations between the various particular sciences within science as an intellectual practice.

The research carried out in order to complete the work on the Copernican Revolution will give Kuhn the opportunity to think about the way in which the history of science is traditionally done. Thus, starting from the case of the Copernican Revolution, Kuhn finds that history was told from a multitude of points of view, without capturing the characteristics that transcend all these unilateral interpretations, and that each researcher looked in isolation at those aspects towards which he directed his attention from the beginning. Or, according to Kuhn, the Copernican Revolution, although interpreted pluralistically, has a common core and an interdisciplinary character:

> "Though the Revolution's name is singular, the event was plural. Its core was a transformation of mathematical astronomy, but it embraced conceptual changes in cosmology, physics, philosophy and religion as well." (Kuhn 1995, vii)

This plurality of the Copernican Revolution allows the researcher to become aware of how different disciplinary fields provide concepts and ideas that "are woven into a single fabric of thought." (Kuhn 1995, vii)

As a result, a correct and complete history of science must take into account the various external conditions, from the economic ones to the cultural ones, and contextually reveal the relationships between ideas in their succession. Thus, although Copernicus himself was a narrow specialist, concerned with an esoteric problem of mathematical astronomy, that of calculating the position of the planets in the sky, the direction of his research was determined by conditions external to astronomy, as were the exploratory researches in medieval physics on the fall bodies, or the Renaissance resurrection of the old mystical philosophy according to which the sun was considered an image of divinity, or the geographical discoveries of navigators that widened the horizon of knowledge.

Together with Kuhn, we can distinguish between three dimensions of the Copernican Revolution: one strictly astronomical, one generally scientific, another philosophical. In the strict astronomical sense, the Copernican Revolution is a reform of the fundamental concepts of this field: through his work, *De revolutionibus orbium coelestium*, published in 1543, Nicolaus Copernicus aimed at nothing more than to increase the accuracy and precision of the theory about the movement of celestial bodies on their orbits by transferring to the Sun those astronomical functions that until then were attributed to the Earth, resulting the Earth losing its unique position as the astronomical center of the universe.

In a general scientific sense, the Copernican Revolution is important for the somewhat unintended consequences it produced in understanding the nature and role of science in society. Copernicus' attempt to improve the predictive power of the theory regarding the positions of the heavenly bodies generated debates about the compatibility of this theory with the traditional view of the universe and became the intellectual ferment of the Scientific Revolution of the 17th century that culminated with Newton's theory. From this perspective, the Copernican Revolution led to a radical change of the conceptions about the universe.

Thirdly, the Copernican Revolution also has a deep philosophical significance. His astronomical theory was a tool able to assure the transition from medieval to modern thought because it influenced the changing image of the relationship between man, the universe and God, as well as, along with this, it produced revaluations and re-significations of the meaning of human existence. Therefore, Kuhn concludes:

> "Initiated as a narrowly technical, highly mathematical revision of classical astronomy, the Copernican theory became one focus for the tremendous controversies in religion, in philosophy, and in social theory which, during the two centuries following the discovery of America, set the tenor of the modern mind." (Kuhn 1995, 2)

The traditional histories of science artificially separated in the mind what was in reality united and thereby lost the authenticity of the process of science development. They either limited themselves to the investigation of certain economic or other external conditions, or followed internally a succession of ideas, or described the cultural diffusion of a scientific invention or idea. Kuhn's proposal is a historical reconstruction that connects all these aspects:

> "We need more than an understanding of the internal development of science. We must also understand how a scientist's solution of an apparently petty, high technical problem can on occasion fundamentally alter men's attitudes toward basic problems of everyday life." (Kuhn 1995, 4)

The main problem raised by the young Kuhn involves an understanding of the old texts in their own intellectual framework of their time starting from their explicit claims and implicit assumptions and commitments. As a result, the historian of science must offer a historical reconstruction of a scientific episode that involves placing it in a context, and by no means an evaluation of the conceptual schemes of the past from the perspective of the concepts and theories accepted in the present. Kuhn resorted to this historical plunge to understand Aristotle and will do the same in the case of the Copernican Revolution. Otherwise, it would mean that we do not understand anything from the old theories, that we wonder how they were accepted, and we consider them as strange or irrational products of the human mind.

3. Why do we accept theories that are later discarded?

Kuhn's problem is rather that of identifying and explaining the grounds that underlie the acceptance of a theory at a given time. Researching the Copernican Revolution allows Kuhn to have some insights into the development of science as a process and the relations between science and society at different stages of science development. Through such historical research, we grasp both the common problematic area and the radical differences between Copernicus' theory and the previous ones, but at the same time, we find that the previous ones were equally credible for those who supported them. However, why were they accepted? The reason for their acceptance was the same for which we later accepted Copernicus' theory: "they provided plausible answers to the questions that seemed important." (Kuhn 1995, 3)

So, theories change, but a theory has its heyday when it is accepted and taken for granted. Kuhn believes that the history of science is an important source to have "a perspective from which to examine the scientific beliefs which it takes so much for granted" (Kuhn 1995, 3-4). Kuhn is surprised by several aspects that were against the traditional image of scientific progress:

- scientific theories do not follow each other cumulatively, but replace each other;
- theories in science are not definitive, they are temporary and they can be revised or abandoned;
- but the old theories were trusted by the members of the scientific community because they fulfilled some explanatory functions specific to science.

Kuhn concludes in an evolutionist vocabulary that anticipates further developments in the "New philosophy of science" and not only that:

> "If we can discover the origins of some modern scientific concepts, and the way in which they supplanted the concepts of an earlier age, we are more likely to evaluate intelligently their chances for survival." (Kuhn 1995, 4)

Starting from the case study of the Copernican Revolution, Kuhn believes that we can obtain conclusions that are valuable for science in general and that we can thus give answers to questions such as "What is a scientific theory? On what should be based to command our respect? What is its function, its use? What is its staying power?" (Kuhn 1995, 4). Even if historical analysis does not provide complete and conclusive theoretical answers to these questions, it can help us to understand them better and it guides us in our theoretical research.

Let's consider the Copernican Revolution as a case study that allows us to understand the mechanism by which a theory is accepted. It is obvious that astronomical observations and theories have an impact on cosmological thinking, that is, on the set of concepts regarding the structure of the universe. Seen in their historical sequence, the cosmologies went further and further from a scientific, technical and systematic point of view, but each one, at its moment of glory, received the consensus of the intellectual community and society as a whole. This consensus is ensured by the fulfilment by each cosmology of two requirements, namely, that of providing an image of the world that satisfies certain psychological needs and that of giving a coherent explanation of the observed phenomena (See Kuhn 1995, 7). Thus, primitive cosmologies are shaped by everyday experiences and by the need to offer for each person the comfort of integration in a universe that they feel like their home. In Kuhn's terms, these cosmologies or cosmological sketches give meaning to everyday, practical or spiritual activities.

Gradually, the second requirement of a coherent explanation of the observations became more important and, finally, it was reached a bifurcation: scientific observations began to play the role of empirical validation for the various images of the universe that were accepted precisely for that they ensured psychological comfort. But things are not quite simple because, according to Kuhn, observations are not neutral or pure, but loaded with theoretical expectations. A first level of these expectations is given by the observational habits that we acquire over time as a result of observing various astronomical regularities, for example, the configuration of the constellations. These act on our mind like a familiar star map and their acceptance is explained by Kuhn with the help of *gestalt* psychology, through the universal need to identify certain familiar patterns in the chaotic flow of experience. Moreover, we can use the star map to make predictions about the position of the sun in the sky in the future. This ability to make such astronomical predictions becomes a mark of scientific knowledge.

We discover here, in a still rudimentary form, two of the theses that will become redoubtable later in Kuhn's philosophy, that of the image of the world as a *gestalt* with a certain structure and that of the theoretical loudness of observation. Both ideas will become key elements in the explanation of the paradigm shift. The theories invented by the astronomers are tentative solutions based on interpretations of observations that are incorporated into the vocabularies used. From here we can reach the paradoxical situation in which "two astronomers can agree perfectly about the results of observation and yet disagree sharply about question like the reality of the motion of the stars" (Kuhn 1995, 26).

Therefore, we accept a theory to the extent that it fulfilled explanatory and utilitarian functions, namely, logical and psychological functions that intertwine and that ensure the theory's resistance over time once we start to believe in it. In short, generalizing, we will say that we fully accept the theories we believe in and ensure a coherent and comfortable perspective on the world.

4. The idea of a conceptual scheme

Kuhn introduces the idea of a conceptual scheme starting from the case study of the astronomical model of "the two sphere-universe". The ancient Greeks were the first to describe the structure of the universe through a conceptual scheme in the form of the two sphere-universe, the inner or terrestrial sphere and the outer or celestial sphere. This image that enjoys the consensus of astronomers and philosophers looks like this: the Earth is a tiny sphere suspended stationary in the geometric center of a much larger sphere that rotates and carries the stars. The sun moves in the vast space between the earth and the sphere of the stars. Beyond the stars sphere there is nothing, neither space nor matter. The sources of this astronomical model are Egyptian and Babylonian, and it corresponds to their observations and their cosmological vision. The ancient Greeks develop the conceptual scheme by articulating the model within a philosophical framework.

Kuhn identifies the main elements that make up this conceptual scheme. First of all, we must mention the Platonic philosophical sources that question a perfect universe, from where it follows that, because it is perfect, it must be symmetrical. This argument based on symmetry is very strong and coherent in ancient thought, although some of its consequences seem strange to a modern thinker. Anyway, the important thing is that this model, a product of the imagination, corresponded with the observations that had been made.

The second element, perhaps even more striking, is that the model of the two sphere-universe achieves a "conceptual economy" (Kuhn 1995, 37) in relation to the complexity and abundance of observations. The two-sphere model compactly summarizes a huge number of observations and is quite useful. It remains valid today, for example, for navigation on the earth, that is, we do not need to take anything else into account; it is enough to assume that the earth is at the center of a rotating sphere. The model is useful to navigators, regardless of whether it represents reality or not. In this sense, from the perspective of conceptual economy, the two-sphere model remains a successful theory.

Symmetry and conceptual economy are logical functions, but the model of the two spheres also has psychological functions that depend on the and beliefs of the scientist. For example, the desire to feel at home can only be satisfied if the scheme offers more than a conceptual economy. The ancients and early moderns even believed that the universe of the two spheres was a real one, and the adjacent cosmology offered an image of the world, established man's place in the universe and provided a meaning to the relationship with God. Therefore, it is quite obvious that a conceptual scheme that functions as part of a cosmology has more than a strictly scientific significance.

Beliefs affect how conceptual schemes work in science. We have a spectrum that has at one end conceptual economy as a purely logical function and at the other intellectual and emotional satisfaction as a purely psychological function. But we have to add other intermediaries. A good example is that of an astronomer who believes in the validity of the two-spheres universe because it provides a synthesis of the observed appearances, but also because that model explains them, leading us to understand them as they are. These two terms, "to explain" and "to understand", seem to refer simultaneously to both logical and psychological aspects. Logically, the two-spheres model explains the motion of the stars as it is deduced reductively from the model. Psychologically, however, the universe of the two stars offers an explanation only if we believe in it. We recognize in this distinction a theme of subsequent debates regarding the distinction between the logic of research and the psychology of discovery as it was drawn in the famous dispute between Popper and Kuhn.

Moreover, the scientist's adherence to a conceptual scheme has a psychological nature: "A scientist's willingness to use a conceptual scheme in explanations is an index of his commitment to the scheme, a token of his belief that his model is the only valid one" (Kuhn 1995, 39). Kuhn warns that such a commitment is always imprudent and hasty because conceptual economy (the logical criterion) and cosmological satisfaction (the psychological criterion) cannot guarantee truth, whatever we mean by "truth".

Given all these theoretical ingredients, Kuhn describes the process of science development as a competition and succession of conceptual schemes, so that we can suppose that all that is missing from this vocabulary previous to *SSR* is the term "paradigm". The history of science is full of the relics of conceptual schemes which "were once fervently believed and that have since been replaced by incompatible theories. There is no way of proving that a conceptual scheme is final" (Kuhn 1995, 39). But these conceptual schemes have another function that consists in their comprehension, namely, their capacity to transcend the known, "becoming first and foremost a powerful tool for predicting and exploring the unknown" (Kuhn 1995, 39). As a result, based on a conceptual scheme accepted at a given moment, we can not only interpret the entire history of a scientific field, but we also have a guide to the future that limits our theoretical choices and exploratory preferences. However, these constraints are weak enough to allow revisions and extensions:

> "Typically, a conceptual scheme provides hints for the organization of research rather than explicit directives, and the pursuit of these

> hints usually requires extension or modification of the conceptual scheme that provided them." (Kuhn 1995, 40)

Thus, the two sphere-universe proved a fertile conceptual scheme that was able to solve some problems of planets motion and that effectively guided the research and was the framework for organizing it.

5. "The anatomy of a scientific belief"

How do we explain this strong resilience of the belief in the central position of the earth, although the problem of the planets revealed serious inadvertences? Kuhn becomes aware of the fact that a scientific community hardly gives up the conceptual scheme that its members share in common. That is why it is not hazardous to say that perhaps even modern man would believe in the universe of the two spheres if the only celestial bodies visible to the naked eye were the sun and the stars. But the planets were also visible. The logical form of Kuhn's argument is one of a reasoning by *reductio ad absurdum*. Kuhn adopts a methodological strategy in which the observations, as a tribunal of experience, are those from which the interpretations derive:

> "Once again we consider observations before dealing with interpretive explanations. And once again the discussion of interpretations will confront us with a new and fundamental problem about the anatomy of scientific belief." (Kuhn 1995, 45)

But he finds that, in fact, already established beliefs were the ones that guided the observations and made them appear as we expected. However, in the case of the problem of the planets, the observations could no longer be adjusted according to our expectations and, therefore, this problem became the source of the Copernican Revolution.

Kuhn considered that the big problem of the two-sphere universe model was to reconcile the irregularities observed in the movement of the planets with a rigorous mathematical theory.

Astronomers believed in their model because it was consistent with all other cosmological and philosophical beliefs and their goal was to create a mathematical tool that would allow a more precise calculation of planets position. The problem of the irregular movement of the planets was an old one that came from Plato and became a great challenge for astronomers, still being "the big question" in Copernicus' time. Ptolemeus was the first to match observations and mathematics through the theory of epicycles, so he offered an astronomical archetype that justifies the statement that Ptolemaic astronomy refers rather to the traditional approach of the planets problem.

Ptolemaic astronomy, in its developed mathematical form, as a system of compound circles, based on epicycles and deferents, was a brilliant achievement, "but it never quite worked" (Kuhn 1995, 73). The greater accuracy was obtained with the price of increased complexity, that is, the addition of new epicycles and other instruments. None of the new more complex versions of the Ptolemaic system stand up to increasingly sophisticated observational tests, and these failures, coupled with the total disappearance of the conceptual economy, that supported the original versions, led to the Copernican Revolution, but it took about 1800 years, an enigmatic longevity that leads to questions:

> "How did the two-sphere universe and the associated epicycle-deferent planetary theory gain so tight a grip upon the imagination of the astronomers? And, once gained, how was the psychological grip of this traditional approach to a traditional problem released? Or to put the same question more directly: Why was the Copernican Revolution so delayed? And how did it come to pass at all?" (Kuhn 1995, 74-75)

According to Kuhn, we have here not only a problem of the history of science, but also one concerning "the nature and structure of conceptual schemes and with the process by which one conceptual scheme replaces another" (Kuhn 1995, 75). From a logical point of view, Kuhn admits in a Popperian style of falsificationism, that we have here a lot of alternatives and the observations should ensure the choice of one of them. But it doesn't happen like that. To explain due to what reasons such thing is possible, Kuhn develops an alternative to Popperian falsificationism. In fact, we never have such observations absolutely incompatible with a conceptual scheme. On the other hand, Copernicus felt that the behavior of the planets is incompatible with the universe of the two spheres.

How to understand this historical fact in which logical incompatibility and psychological constraints mix contradictory? How can a conceptual scheme that one generation finds subtle, flexible, and complex become obscure, ambiguous, and unwieldy for the next generation? Why do scientists insist on supporting theories despite the discrepancies, and why, after having supported them, do they abandon them? How do we explain the strength of a tradition? Here are all the questions that will lead Kuhn to the theoretical developments from *SSR*.

In *CR* Kuhn explains at length how the astronomical model of the two spheres was incorporated into a complex fabric of non-astronomical beliefs. Likewise, the Copernican model will be part of such a complex system of beliefs. Therefore, *The Copernican Revolution* should not be reduced to a simple change regarding the position of the earth and the sun, but, viewed in its multiplicity of relations with fields external to astronomy, as a change in our worldview (Kuhn 1995, 94). This does not mean that nothing happened between Aristotle and Copernicus. On the contrary, intense work was done, immense intellectual energies were expended, but the Ptolemaic conceptual scheme was not questioned. And when this happened, it was produced not only by the internal problem of the planets, but also by the fact that the external, non-astronomical intellectual environment, had prepared such a change. The processes described here will later be named by Kuhn using the terms of the *SSR* vocabulary, from "normal science" to "disciplinary matrix".

6. The lessons given by *The Copernican Revolution*

According to Kuhn[3] we may distinguish between two aspects that a historical research of *The Copernican Revolution* reveals:

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[3] It is interesting to mention that Kuhn returned to and revised his conception of science development outlined in *SSR*, but he did not return to the case study from

1. Considered as a typical scientific theory, its history is illustrative for the processes by which scientific concepts evolve and by which new concepts replace old ones.
2. Considered from the perspective of its extra-scientific consequence and of all its influences outside science, the Copernican theory is exemplary for the case of some theories, few in number, which produced large-scale changes in the external intellectual environment and determined reorientations of Western thought, such as Darwin's theory, Einstein's theory of relativity, and Freud's psychoanalytic theory.

If we look at the sequence of the two sphere-universe model and of the Copernican model, then we will conclude that the two are different, but the second was possible just because the first was developed till is the last consequences. Kuhn does not yet introduce the thesis of incommensurability, but accepts a dynamic based both on continuity in solving certain problems, such as the calculation of the planet's positions, and on a break at the basic level, such as the admission by the Copernican model of the hypothesis of a planetary earth:

> "The Copernican universe is itself the product of a series of investigations that the two-sphere universe made possible: the conception of a planetary earth is the most forceful illustration of the effective guidance given to science by the incompatible conception of a unique central earth. (...) The two-sphere universe is the parent of the Copernican; no conceptual scheme is born from nothing." (Kuhn 1995, 41)

It is obvious that incompatibility does not mean incommensurability here yet and that this second concept will be one of the novelties in SSR together with all its radical theoretical consequences for the understanding of science history.

CR. Such a reconstruction of the case study from the perspective of changes in Kuhn's conception of science development is proposed by Westman (1994).

Instead, although he does not use the concepts of paradigm and pre-paradigmatic phase, Kuhn describes in *The Copernican Revolution*, when he talks about the competitors of two sphere-universe, a state of scientific knowledge that has all the attributes of a pre-paradigmatic phase.

The model of two sphere- universe was not the only one proposed by the ancient Greeks, there were alternative models. It was eventually accepted from many alternatives, although some of the cosmological contenders looked more like the Copernican model of modernity than the two-sphere model. It is enough to mention the model of infinite worlds proposed by Leucippus and Democritus before Aristotle, or the model proposed by Heraclides Ponticus, contemporary with Aristotle, who suggested that there is a diurnal movement of the Earth, and not a rotation of the celestial sphere, or the model more later, from the 3rd century, proposed by Aristarchus of Samos, also called "the Copernicus of antiquity", which assumed that the Earth revolves around the Sun. However, most ancient philosophers and astronomers rejected these alternatives because they lacked the arguments that later supported the Copernican model. The main reasons to reject them were these:

> "These alternative cosmologies violate the first and most fundamental suggestions provided by the senses about the structure of the universe. Furthermore, this violation of common sense is not compensated for by any increase in the effectiveness with which they account for the appearances. At best they are no more economical, fruitful or precise than the two-sphere universe, and they are a great deal harder to believe. It was difficult to take them seriously as explanations." (Kuhn 1995, 43)

The observations suggested that the first astronomical distinction we must make is that between the earth and the heaven and that it would be absurd to believe, based on these observations, that the earth moves. Therefore, if we take these observations into account, then the difficult problem would not be to explain why the model of the two sphere-universe was derived from them, but why this model was abandoned.

Again, in a way that anticipates the ideas form *SSR,* Kuhn identifies that problem that gradually became an anomaly in relation to the model of the two sphere-universe and generated efforts to solve it. Kuhn does not yet use a vocabulary that contains the term "anomaly" and the expression "extraordinary research", but the situations he describes in *CR* are similar to those to which the two expressions will refer. Kuhn also mentions the problem of the ingredients of a disciplinary matrix and highlights the role of various philosophical beliefs, in the case of Copernican Revolution the rediscovery of Platonism by the Renaissance.

Indisputably, the conceptual scheme developed by Kuhn in *CR* is based on his new approach to the intellectual history of science which consists of historical reconstructions as case studies. Kuhn derives from the case of the Copernican Revolution many of his theoretical theses that will then be coherently assembled in a new vision of the development of science presented in *SSR*.

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