THE HEURISTIC ROLE OF QUESTIONS IN THE FORMATION OF RESEARCH PROGRAMMES: COPERNICUS'S HELIOCENTRIC SYSTEM

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ABSTRACT

THE HEURISTIC ROLE OF QUESTIONS IN THE FORMATION OF RESEARCH PROGRAMMES: COPERNICUS'S HELIOCENTRIC SYSTEM

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The aim of this thesis is to develop a critical view about the notion of the *heuristic* in Lakatos's methodology of research programmes. The *heuristic* is tried to be sterilized from its defects with an insight derived from different forms of theories dealing with questions. For that reason, a short survey which includes Socratic dialogues, Hintikka's theory of interrogative games, van Fraassen's theory of why-questions, and Laudan's analogy between science and problem-solving activity is introduced. As a result, the *heuristic* is construed as the interrogative tools that an inquirer has to construct her theories and solve their problems. The Copernican Revolution is endeavoured to be reconstructed as a case study in the lights of the questions that Copernicus might pose to discover his heliocentric cosmology. Since the Copernican programme cannot be reduced to the theories of Copernicus alone, only the primitive form of this programme which could be associated with Copernicus is examined to check the verity of this newly formulated definition of the *heuristic*.

Keywords: questions, interrogative theory, heuristic, research programmes, Copernicus

ÖZ

ARAŞTIRMA PROGRAMLARININ OLUŞUMUNDA SORULARIN HÖRİSTİK ROLÜ: KOPERNİK'İN GÜNEŞ-MERKEZLİ SİSTEMİ

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Bu tezin amacı, Lakatos'un araştırma programları metodolojisindeki höristik kavramına dair eleştirel bir bakış açısı geliştirmektir. Sorularla uğraşan farklı teorilerden türetilen bir görüyle höristik, kusurlarından arındırılmaya çalışılmaktadır. Bu gerekçeyle, Sokratik diyaloglar, Hintikka'nın sorgulayıcı oyunlarını, van Fraassen'ın niçin-soruları teorisini ve Laudan'ın bilim ve problem çözme aktivitesi arasında kurduğu benzetmeyi içeren küçük bir inceleme sunulmaktadır. Sonuç olarak höristik, bir araştırmacının teorilerini kurmak ve problemlerini çözmek üzere sahip olduğu sorgulayıcı araçlar olarak tanımlanmaktadır. Kopernik Devrimi ise güneş-merkezli kozmolojinin keşfi için Kopernik'in sormuş olabileceği sorular ışığında yeniden inşa edilmeye uğraşılmaktadır. Kopernikçi programın tek başına Kopernik'in teorilerine indirgenemeyişinden ötürü, programın Kopernik ile ilişkilendirilebilecek yalnızca ilkel bir formu, höristiğe dair yeni formüle edilen tanımın doğruluğunu kontrol etmek için sınanmıştır.

Anahtar Kelimeler: sorular, sorgulayıcı teori, höristik, araştırma programları, Kopernik

Let no one untrained in philosophy enter here.

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CHAPTER 1

INTRODUCTION

Reasoning via questions is a practice employed by many figures in the history of philosophy and science. Most philosophers and scientists have utilized questions deliberately or unintentionally, and been assisted by them in discovering new paths to consider for their inquiries. While the questions preoccupied with “meaning” are mostly associated with philosophical activities, questions pointing a “world-fact” are assumed to be asked by a scientific interest (Uygur, 1964, p.72).[1] In this separation, scientific inquiry is depicted as an attempt to interpret the world by examining the fact, whereas philosophical inquiry is treated as a concern about the meaning of definite words, rather than realities going beyond these words in question. Although both of them can deal with the same phenomena, the way of how these two types of inquiry handle the questioned phenomena alters. While scientific questions have recourse to the phenomena of words and are exhausted on the world, philosophical questions look into this phenomena-through-language and are exhausted within the realm of language (Uygur, 1964, pp.77-80). In terms of the form of questioning, the philosophical interrogation is tended to be characterized by the question-pattern of “what-is”, but the inquisitive act of the scientists is usually exemplified by “how” questions (Uygur, 1964, p.78). For instance, “What is the meaning of world?” is a philosophical question, but “How is the world made up?” is a scientific question.

[1] Uygur also refers here to the ordinary sense of questioning the world-fact in everyday deeds such as asking the number of rooms by pointing out a particular house. However, such a mundane practice of questioning is out of the topic of this paper.

When we go back in history and research the primitive forms of interrogative reasoning, we firstly encounter with the philosophical questions in the form of "what-is". This type of inquiries mostly resembles the pattern that is followed by the question-and-answer dialogues. This simple form of interrogation performed between two parties aims to get an answer to big (principal) questions through directing smaller (operative) questions to the opponent (Hintikka, 1999, p.67). Platonic or Socratic dialogues are competent examples of this kind of reasoning whose formal structure imitates what two human speakers do in a conversation in everyday life. Of course, the content of the Greek example is much more philosophical. Basically, Socratic method adopts stimulating one's thoughts by a question-and-answer dialogue, and aims to demonstrate the inconsistency within one's most fundamental opinions. Acknowledging the standard interpretation, a typical Socratic dialogue begins with a question searching for a definition such as "What is X?" The basic rationale behind the Socratic Method is, gradually, making one's "indigested opinions" examined, invoking one to verify his assertions, showing the necessity of modifying his beliefs by the technique of *reductio ad absurdum*, and releasing him from his prejudices (Thilly, 1951, p.64). The subject of early dialogues is mainly the definitions of terms in the domain of ethics and politics such as piety, justice and citizenship. Socrates invites any person to a discussion with himself and encourages him to make an argument to define such basic concepts. With the help of illustrations from everyday life, he endeavors to display fallacies in his opponent's argument. Socrates continuously produces negative instances about the definition of his opponent until managing to make him realize the unfoundedness of his initial assumptions. Socrates forces his opponent, by questioning, to discover indispensible features of the subject to be defined and enables him to have clear and distinct concepts (Thilly, 1951, p.67).

Socratic method is also called as *maieutic method* because of not dictating his own truth but rather leading one to discover the truth on her own. However, this method still has some problematic restrictions. Firstly, it can only be used to study interrogative arguments with a predetermined ultimate conclusion (Hintikka, 1999, p.67). Socrates allows his opponent, the respondent, to depict his own path but the point of arrival is always decided by the questioner, Socrates himself. The respondent inevitably finds himself to agree the questioner's conclusion because his severe criticism forces the respondent to finish his inquiry at a point which has been found reasonable by the questioner since the beginning. Therefore, this method of reasoning can only be applied to reanimate the inquiries whose conclusion is already known by the questioner. So, the questions employed by such reasoning are not capable of leading the questioner to discover or acquire new information. Secondly, this simple form of interrogative reasoning does not explain the relationship between the question and its (conclusive) answer (Hintikka, 1999, p.67). In other words, the conclusiveness criterion for the set including the question and the answer is not satisfied by the simple form of interrogative reasoning. Since any answer providing any relevant information for the overarching question is supposed legitimate in Socratic dialogues, the singular relation between a specific question and its conclusive answer cannot be supplied. As long as the respondent's final destination is what the questioner envisages, the respondent becomes free to follow the path whatever he wants. So, the thinking way of the inquirer to discover cannot be represented as it is desired by the principle of conclusiveness.

Another approach to criticize the Socratic method can be derived from van Fraassen's theory of why-questions. Similar to the second criticism of Hintikka, van Fraassen takes a position about the relation between a question and its answer by offering a notion as the *direct answer*. Nuel Belnap's theory of questions, especially the theory of elementary questions such as whether-questions and which-questions, is the main inspiration of van Frassen for this position (van Fraassen, 1980, p.137). To sketch the basic motivation of Belnap's theory, it can be said that a question is expressed by an interrogative in a similar fashion that a proposition is articulated by a declarative sentence. Like the distinction between propositions and sentences, answers are distinguished from responses. In propositional theory, not all sentences signify propositions. Since sentences can have many meanings, it complicates which of these meanings will be adressed. The interrogative theory requires a very much alike distinction between the answers and the responses. While nearly every single thing can be a response to a question, not all of the responses can be answers. For a theory of questions, the degrees of responses to be answers should be designated and a sort of catalog for the types of answers should be developed for a reference point. To avoid the possibility of that every proposition can be an answer to any question, a pure example of an answer should be offered, too. Van Fraassen calls this kind of an answer as a *direct answer* and defines it as a proposition which gives enough information to answer the question completely, neither less nor more than that (van Fraassen, 1998, p.138). Basically, a *direct answer* has to fulfill the request of the question by satisfying two claims which are distinctness claim and the completeness claim. The respondent is expected to make a selection among the alternative responses to a question, or to put it differently, to distinguish one alternative from the rest of the set. This is called as the distinctness claim. This selection of the respondent should also be for a specific reason which is the same with the requested information by the question. This entails the completeness claim. This is a very similar claim to what Hintikka calls as the principle of conclusiveness.

To solve the problems of the simple form of interrogative reasoning which is traditionally exemplified by Socratic dialogues, Hintikka offers a solution which is compatible with the basics of the theory of questions. He suggests an epistemic modification for this elementary structure, and in this way, he plans to explicate interrogative inquiry as “a search of knowledge” (Hintikka, 1999, p.67). By his annotation put to Socratic archetype, we are entering to the region of scientific interrogation occupied with how-type of questions. The goal of questioning is being transformed into a search for information about the world-fact. Before giving the details of Hintikka’s theory, van Fraassen’s theory of why-questions should be clarified here to strengthen the link between the questions and the scientific inquiry. Even though there is a discussion about which type of questions should be answered by the science: “how” or “why”, I try to stay out of this debate. I will not defend the distinction between the questions seeking how and why of the phenomena as mostly advocated by those who relate why-questions with a teleological stand and so, push them outside the scientific domain.[2] What I argue will simply favor that questions can be rephrased and a why-question can be transformed into a “How can we explain…?” type of question. It is important to note that my position here is closer to Cross, rather than van Fraassen.[3] Now, I can start to elaborate van Fraassen’s theory of why-questions to picture questioning-process as a way of seeking for explanations. What he fundamentally claims is that the explanations of the scientist can be formulated as her answers to why-questions. To answer them well, the scientist has to characterize three factors in her inquiry: *topic*, *contrast class*, and *relevance relation* (van Fraassen, 1980, pp. 141-142). First of all, the *topic* is the sub-sentential part of a why-question, which follows the question word. For instance, the topic becomes P in the question of “Why is P?” Secondly, the *contrast class* is composed of propositions which are alternatives of P such as $\{P_1,P_{2,\ldots,}P_n\}$. It is the set of possibilities that the scientist wants to appraise. Finally, the *relevance relation* limits the possible answers by designating an explanatory factor. This relation specifies the context in which the question is asked and according to which the possible answers should be evaluated. A very same question can relate a topic with different contrast classes and can wait different explanations. For instance, the question “Why did Adam eat the apple?” can be formulated differently and so, the question can require different kinds of explanation. Three possible formulations can be

[2] The existence of teleological notions within science is a topic mostly discussed in biology, especially in Darwin’s theory of evolution. The parties of the discussion are divided as those who advocate that teleological notions should be eliminated to prevent the intervention of the scientist to the objective processes of the scientific activity and those who defend that those notions are ineliminable properties of biological explanations (Allen, 2009).

[3] As oppose to van Fraassen's theory of why-questions, Cross argues that not only the why-questions but also the how-questions are explanations. He offers a ground for unifying these two types of questions on the ground of a single theory of explanatory questions (Cross, 1991).

made as follows: “Why did *Adam* eat the apple?”, “Why did Adam *eat* the apple?”, “Why did Adam eat the *apple*?” (Sandborg, p.608) The contrast class of the first formulation involves the people, including Adam, who could have eaten the apple. The second is composed of the possible actions, including eating, that could have been done with the apple by Adam. The third one consists of the things, including the apple, which could have been eaten by Adam. So, an answer such as “Adam ate the apple because he was hungry” can be satisfactory only for the second formulation of the question.

Van Fraassen’s theory of why-questions can be regarded as a kind of preliminary work for Hintikka’s theory of interrogatives. Since he tries to figure out an interrogative logic of information-seeking, treating questions as means of explanations is a way of endorsing the epistemic nature of the questioning process. In that sense, the epistemic adjustment of the basic form of interrogative theory is agreeable to van Fraassen’s theory. However, Hintikka’s theory enjoys the analogies with mathematical sciences more than van Fraassen.[4] Hintikka compares the couples which consist of a question and an answer to the successive turns of a game, and formulates question-answer sequences in the form of games as those which are in the mathematical theory of games (Hintikka, 1999, p.121). In this new method, the gain of the inquirer from the questioning practice is characterized in a stronger manner in comparison with the basic form of the interrogative theory. The earnings of the Hintikka’s inquirer transcend the gain of the Socratic inquirer. Instead of characterizing the questioning-process as it starts to obtain an agreement between two minds and ends when the opinions are reconciled, Hintikka identifies the questioning-process as it continues until the questioned phenomenon is discovered in all aspects. The value of questioning in Hintikka’s theory is not solely about challenging ill-constructed opinions of other questioners. In addition to that, the

[4] According to David Sandborg, van Fraassen’s theory of why-questions is not applicable to mathematical explanations, because mathematical explanations cannot be regarded as answers to why-questions (Sandborg, 1998). Offering a mathematical proof as an explanation creates an expectation that the proof will fill some missing information. However, a proof just extends the consequences derived from previously given propositions. So, a proof cannot add information, and cannot give explanation in van Fraassen’s sense.

questioning is considered as valuable because it promises to the questioner herself to acquire new pieces of knowledge. This promise of course can be kept if an epistemic value is embraced by the questioning practice. In portraying the scientific inquiry as an interrogative game, Hintikka aims to achieve this by taking his cue from Kant's *Critique of Pure Reason* (Hintikka, 1999, p.119). In the second edition, Kant argues that:

> [Reason] must take the lead with principles for its judgments according to constant laws and compel nature to answer its questions, rather than letting nature guide its movements by keeping reason, as it were, in leading-strings…Reason, in order to be thought by nature, must approach nature with its principles in one hand…, in the other hand, the experiments thought out in accordance with these principles- yet in order to be instructed by nature not like a pupil, …but like an appointed judge who compels witnesses to answer the questions he put them (Kant, 2009, preface, B xiii)

By depending on the idea represented in this quotation, Hintikka describes scientific activity as series of questions which are put by the investigator to the nature. The scientist selects these questions in accordance with the plans and the principles of her own in order to direct her inquiry. In Hintikka's formulation, scientific inquiry becomes an interrogative game in which the scientist interacts with nature dialectically (Hintikka 1999, p.140). The scientist puts questions to the nature, gets some answers from it through her observations, and learns a little bit more about the intrinsic structure of the dynamics of science. This Kantian structure is preserved in Hintikka's interrogative games where the scientist -or the Inquirer- asks, the Nature answers. The game aims to make the players, the Inquirer and the Nature, race with each other by assigning different tasks for each. The Inquirer tries to answer the initial (principal) question either by confirming its truth, "C", or demonstrating its opposition, "not-C". However, the Nature tries to prevent the Inquirer, without cheating, to end the inquiry with a success (Hintikka, 1999, p.128). The Inquirer is let to move in two ways, which are deductive and interrogative moves. When it is the Inquirer's turn, it asks a question and tries to reveal and expand the information which is implicit within the initial premise. The more it asks, the more answers it gets. When these answers are enough for deriving new information from the initial premise, the Inquirer makes a deductive move. In this line of moves, the Inquirer comes closer to prove either "C" (exclusively) or "not-C".

The depiction of Hintikka's scientific inquiry in the form of a turn-based board game allows players to use questions as means of discovery. Unlike the relatively trivial goal of Socratic dialogues, the Inquirer in Hintikka's model has an epistemic motivation in the act of questioning, which is seeking for new information. One of the concerns of Hintikka is also benefiting from this game-analogy for modeling the scientific inquiry, itself. He wants to pay back to the science whose intrinsic dynamics helped him to explore the information-seeking-processes. With the help of the things that he learned while constructing his game-analogy, Hintikka tries to define "problem-solving" as a criterion for the appraisal of scientific theories, which is a project originally belongs to Larry Laudan (Hintikka, 1999, p.119-120).[5] According to Laudan, seeing science as a problem-solving activity can gain a new perspective to the disagreements about the scientific standards or problematic issues about historiography of science (Laudan, 1977, p.12).[6] Rather than the classic measures for theories such as the high degree of confirmation or the explanatory power of theories, an evaluation of theories according to their problem-solving power can be more helpful to define the characteristics of science. Laudan's main thesis for this alteration is as follows: "The first and essential acid test for any theory is whether it provides acceptable answers to interesting questions: whether, in other words, it provides satisfactory solutions to important problems" (Laudan, 1977, p.13). These lines of Laudan give inspiration to Hintikka to complete his predecessor's project (Hintikka, 1999, p.120). Only dealing with the historical examples and not offering a structure to formalize this evolution of problem-solving ability are pointed out

[5] For the main arguments of Laudan, his *Progress and Its Problems: Towards a Theory of Scientific Growth* (1977) can be suggested.

[6] Laudan's analogy between the scientific activity and the problem-solving activity easily reminds the puzzle-solving analogy of Thomas Kuhn (Kuhn, 1996). He identifies the progress of science, in its normal phases, with the success in solving puzzles. In Kuhn's theory, the dominant theory at the time introduces a paradigm as exemplar. This paradigm puts itself as the standard of solving puzzles. It generates new puzzles for the scientists and leads them to solve these puzzles properly.

by Hintikka as the defects of Laudan's project. To replace his scientific enterprise with a better version, Hintikka attempts to provide a real logic or model for these signifying ideas. He endeavors to "construe the scientific enterprise as a questioning procedure" and develops his game-analogy through Beth's semantical tableaux (Hintikka, 1999, pp.120-122). Here, I will not go into the details of this formal language. The point in his theory that attracts my attention is not the formalization, but rather the concept of problem-solving, which also excites Hintikka from Laudan's project. The transformation of the concept in Hintikka's theory into a neo-Kantian project and the replaced role of the traditional "reasoner" by the "Inquirer" ease my job to some extent. However, the underrated value of the history in identifying the scientific enterprise as a growing ability to pose questions to nature is my main concern. To express my hesitation about Hintikka's way of approaching to the phenomenon of problem-solving, Lakatos's dramatic statement could be quoted: "Philosophy of science without history of science is empty; history of science without philosophy of science is blind" (Lakatos, 1981, p.107). Not surprisingly, my suggestion will be setting a course for the exposition of the concept of problem-solving with the help of a methodology where the history and science go hand in hand. But first of all, I should make myself clear about why the history of science is substantial for the philosophy of science and how the convergence of two will help me in this study.

What is learned above from the critical evaluation of Hintikka's theory can be summarized as follows. The role of the historiography in constructing methodologies for scientific activity should not be underestimated. Without appearing in the "tribunal of history"[7] and managing to survive there, the reception of theories to the scientific community is hardly be confirmed (Larvor, 1998, p.50). A platform for testing the validity of the inquirer's reasoning to construct her theory is intensely required. When theories are considered as the consequences of the improvement in the ability of problem-solving, or more practically, as the end products of questioning practice, it is

[7] Or "tribunal of experience" in Quine's phrase (Newton-Smith, 1981, p.80).

easier to set up this area of agreement for appraising them. The flux of questions asked and answered from the very beginning to the maturation of theories can form a track which represents the successive stages of the inquirer's reasoning process. Following this track can give a clear picture about how the inquiry is initiated, expands, faces with problems, is systemized, and narrows down for focusing to the solution. This kind of a depiction also provides practical compartments for the re-evaluation of theories by taking their construction-processes into consideration. By grouping the inquirer's answers given for particular questions of the inquiry, a thoroughly organized and well-segmented theory can be achieved. Thus, the improvement in the ability of the inquirer to answer questions, or to solve problems, can be apprehended. That is to say, series of questions can be used as a kind of guide which keeps the critics on the right track, firstly, to testify how the theory is discovered, then, to judge it properly. The series of questions can help with the disclosure of the logic of the theory's discovery. At the same time, they can prescribe a good start for the appraisal of the theory by matching the criticisms with the right question-compartment of the inquiry.

The idea of treating history as an exhibition hall for theories is originally taken its cue from Lakatos's *The Methodology of Scientific Research Programmes* (Lakatos, 1978). He assumes that theories should not be tested individually as the naive falsificationism does, but rather historically. Since the history of science is not a history of isolated theories, but rather the history of research programmes, the descriptive unit of science is supposed not to be individual hypotheses, but rather a set of theories (Lakatos, 1978, p.47, footnote 6). For a fair assessment of theories, a historical story or, more properly, a methodological approach to the falsificationism is suggested by Lakatos. In this verification model, not only the refuting but also the corroborating instances of the excess information are valued (Lakatos, 1978, p.36). As oppose to Popper's one-sided theory of learning from experience, Lakatos claims that one can learn not only from the refutation, but also from the corroboration (Lakatos, 1981, p.116, footnote 25). As he claims, theories should not only be identified according to their failure in the face of anomalies, which provides a negative criterion for the evaluation of theories. But also, a positive criterion should be considered for evaluating them such as their achievement in overcoming anomalies. It is very significant to perform this overall appraisal by considering all of the theories which succeed each other in a research programme. In that sense, research programmes are symbolized as “evolving systems of assertions”, and it is preached that they should be evaluated dependently on their historical content (Newton-Smith, 1981, p.79). A rational picture for the scientific activity is also drawn by this methodology. Some rules deciding who to be the winner of the competition among rival theories and some principles to enable the progress of science through these competitions are determined. However, this part of Lakatos’s theory about the rationalization of the progress in science will be explained later.

The central claim of this paper is offering questions as means of contributing to the definition of a specific concept within Lakatos’ theory, which is *heuristic*. By making this suggestion, I aim to give a clearer description for this concept and increase its ability to discover the characteristics of scientific activity by evaluating the cases from the history of philosophy and science. I will not prefer to use an ambiguous definition for *heuristic* and will not define it traditionally as a “powerful problem solving machinery” (Lakatos, 1978, p.5). Rather, I will propose a more elaborated and hopefully more promising picture for this concept. The *heuristic* will be described in this paper as the interrogative tools of the inquirer to construct her theory and to solve its problems. Roughly, these tools will be defined as including sets of questions which are primarily used for the discovery of the theory, and then, are auxiliary for its appraisal. After illustrating the *heuristic* with the help of the guidance of questions, I will attempt to elucidate their role in discovery with a case study. Copernicus as the pioneer of the project of building a heliocentric research programme will be studied. His attempt to digest anomalies in Ptolemaic model for re-dignifying the Aristotle’s celestial physics will be analyzed in the light of his revolutionary questions.

CHAPTER 2

LAKATOS'S HEURISTIC AND A CONTRIBUTION TO ITS DEFINITION

2.1. The Definition of the Heuristic in Lakatos

Even though there is no clear-cut definition for the concept of *heuristic*, Lakatos makes a description for it through its roles. Basically, *heuristic* is responsible from suggesting some tools for overcoming the problems that are pointed out either by internal mechanisms or external criticisms. The programme can detect its own anomalies by figuring out some inconsistencies among its theories or these anomalies can be addressed by rival programmes. In any case, the role of *heuristic* divides into two as negative and positive. While the *negative heuristic* is prohibiting any change in the hard-core and so, strengthening the proponent's hand, the *positive heuristic* serves for the opponents and enables their criticisms to be encountered by the protective belt. Lakatos defines them as the methodological rules of "particular" research programmes and claims that the *negative* tells us "what paths of research to avoid", whereas the *positive* "what paths to pursue" (Lakatos, 1978, p.47). The *positive heuristic* also plays a role as a kind of "research policy" or "order of research" (Lakatos, 1978, p.50). This policy is composed of a roughly outlined set of recommendations or hints on how to alter, sophisticate, and improve the refutable variants of the research programme. While the irrefutable parts rest in the hard core and shielded by the *negative heuristic*, the refutable parts are embodied by the protective belt and go under change controlled by the *positive heuristic*. It saves the scientist through some instructions from becoming disoriented by the "ocean of anomalies" and keeps her attention on building her model (Lakatos, 1978, p.50). These *positive* and *negative* tips for preparing an inquiry for the hard times which are specific to each programme perform a double-sided task. These tips block the access of criticisms to the hard-core for a quick falsification of the fundamental theories, but also benefit from the criticisms to modify problematic parts of the auxiliary theories within the protective belt. By fulfilling this overwhelming task, it is expected especially from the *positive heuristic* to save the respectability of theories without being a dogma. If the *positive heuristic* becomes successful in this task, it brings a high degree of autonomy to the scientific theories, which cannot be possessed by the "naïve falsificationist's disconnected chain of conjectures and refutations" (Lakatos, 1981, p.116).

For more on how to define *positive heuristic*, we can refer to its service as "an advance warning system" (Newton-Smith, 1981, p.84). Since the problems to be handled for the improvement of the research programme are decided by the *positive heuristic*, it is the one in charge, not the anomalies, for shaping the next steps of the programme (Lakatos, 1981, p.116). Thus, thanks to the *positive heuristic,* the possibility of detaching fallible concepts or imperfect empirical results can be recognized. Like an early diagnosis, *positive heuristic* "defines problems, foresees anomalies and turns them victoriously into examples according to a preconceived plan" (Lakatos, 1978, p.149). The *positive heuristic* identifies a list of suggestions to show how these problems can be resolved immediately after their transformation into anomalies is implied. So, the problems can grow into corroborating examples of the programme by some legitimate modifications. A risk here is failing in modifying the problematic assumptions and being ended up with some "*ad hoc* strategems" (Lakatos, 1978, p.56). A theory is considered as *ad hoc* if the explanation given by the theory for a specific phenomenon is "not independently testable by experiments of a new kind" or "not getting any nearer to truth" by obtaining verifications of new predictions (Popper, 1962, pp.244-246). Lakatos also defines three kinds of *ad hoc-ness*. The first type (*ad hoc*$_1$) consists of auxiliary hypotheses which have no extra empirical content as against the rival programme. The second type (*ad hoc*$_2$) includes hypotheses which have extra content but none of them are corroborated. The third type (*ad hoc*$_3$) differs from the first two in terms of not being necessary for the *positive heuristic* (Lakatos, 1981, p.117, footnote 27). Not all of the auxiliary hypotheses in the protective belt have *heuristic* value, and the hypotheses of the third type are regarded as *ad hoc* because of this feature. When one of these three types is detected, it is understood that these research programmes are patched either by chance discoveries or by the facts which are projected by rival programmes and not able to be internalized. Since its development in problem solving, if there is any, is not a consequence of a pre-planned *positive heuristic*, their problem-shift is acknowledged as degenerating.

Another, and also the final, interpretation of *heuristic* can be offered by bringing its most general character to forefront, which is the *heuristic* as "patterns that we can learn, follow or avoid, as well as improve" (Kiss, 2006, P.306). It can be formalized as a reasoning style, a methodology of thinking, or "a continuous pattern of the growth of knowledge" (Lakatos, 1976, p.93). Lakatos himself also defines the methodology through its similarities with Pólya's "heuristic" and Popper's "logic of discovery" (Lakatos, 1976, p.3).[8] The early version of Lakatos's heuristic, in his *Proofs and Refutations,* resembled what Pólya wanted to figure out in mathematics, which was "a theory-neutral body of techniques of discovery" (Hacking, 1981, p.134). In this sense, the primitive form of his *heuristic* was much more about the logic of invention or conjecture-production unlike the base of Popper's investigation, which gives primacy to the logic of evaluation.[9] According to Lakatos's early-stage theory of *heuristic*, withdrawal of anomalies or counterexamples is not welcomed, because this move can

[8] Popper's "logic of discovery" literally refers to the illogical character of discoveries. According to him, the rationality of scientific progress is constructed by the logical structure of theories which are exemplified only in the process of justification.

[9] Popper's logic of evaluation is rooted in the demarcation principle between the statements of the empirical sciences and the statements which have a metaphysical character. In this respect, the evaluation criterion is determined as the "testability" criterion, which is also named as the "falsifiability" or "refutability" (Popper, 1962, p.39).

decrease the number of phenomena which the theory can give a demonstration of. Instead of seeing them as monsters and avoiding them, a kind of "hidden lemma" or disguised descriptor should be searched to explain the existence of these counterexamples and to benefit them to correct the proof (Hacking, 1981, pp.134-5). In this way, it is aimed to extend the reach of the theory by tolerating anomalies and let them to lead us new classes of examples which are applicable by the proof. Thanks to the fresh instances of confirmation which were once anomalies, tools of discovery can be improved and the explanatory power of the theory can be increased. It is also argued that such mathematical heuristics can be found in the scientific activity either by looking at the history of science in general or by analyzing individual scientist (Kiss, 2006, p.306). Since individual scientists create a bond with the history of science via the activity of problem solving, they become a part of the historical debates. They are freed from the bounds of time and space. Even though the birth of theories belongs to the different segments of history, the scientists are able to discuss with their predecessors theoretically. Even, they can debate with themselves. Like in Pólya's definition, a scientist can put questions to oneself to activate the process of problem solving and so, to engage in an "inner dialog" (Kiss, 2006, p.306). Both of these ways, extrinsic or intrinsic, for triggering the creative aspects of the scientist are considered as the simple forms of *heuristic*.

It also should be noted that Lakatos's definition for *heuristic* was subjected to many variations through years. Even though the first sense of the concept was borrowed from Pólya, it became a general theory of rational change and growth. More broadly, it turned into a theory of rational practice in science in Lakatos's *Proofs and Refutations* (Larvor, 1998, p.53). He benefited from Pólya, in taking recommendations about how mathematics, or science generally, advances on solving problems. Pólya's theory about "good research advices" which was achieved through an activity on handling mathematical concepts, also called as "concept-stretching",[10] gained a new and more local meaning in *The Methodology of Scientific Research Programmes* (Larvor, 1998, p.53). *Heuristic* turned into a problem-solving tool which gives specific instructions for each single programme. The whole evolution of Lakatos's *heuristic* can be summarized in a similar fashion to Hacking's categorization as in the followings (Hacking, 1981, p.135). Firstly, it was a "methodology-*heuristic*" and looking forward, which means that it was telling how to solve and how to proceed. Then, it was divided into two as "methodology" and "*heuristic*". The former was a "backward-looking" approach to identify what was the essence of the growth of knowledge. The latter was the "forward-looking" *heuristic* which lost its general character and began to localize its strategies for each programme. At the current stage of its evolution, the *heuristic* is able to have some bold mottos about how theories grow into programmes, or how they can be adjusted in the face of anomalies. But still, a general form of *heuristic* as a global maxim is not the case anymore.

Even though the universal character of *heuristic* was damaged through its evolution, Lakatos did not avoid to be engaged with other theories for improving effective criterion for the theoretical distinctions in his methodology. For instance, Popper's "third world" attracts Lakatos's attention in defining the internal history (Hacking, 1981, p.137). Basically, the trichotomy of Popper's worlds is composed of the "first" which is the world of matter, the "second" which is the world of feelings, beliefs, and consciousness, and finally the "third world" that of objective knowledge which are expressed in propositions. The third world in Popper is much more a conjecture on which human knowledge acquires its own definitions and laws. Lakatos uses a metaphor to categorize these worlds under two titles: the products and producers of human knowledge (Hacking, 1981, p.137) While the products such as theories, research

[10] It means stretching a theoretical term in a theorem with the aim of including some exceptional examples, which are once-anomalies (Lakatos, 1976, p.99). Lakatos believes that what we mean by referring to a term is determined by our ability to prove it. So, nothing as inelastic and certain can survive in mathematics, of course with a upper limit of the elasticity (Lakatos, 1976, p.102).

programmes, problems, and problemshifts live in the third world, the first and the second worlds host the producers. Being inspired by Hegel, Lakatos claims that mathematics as a product of human activity "alienates itself" from its producer, and only in this way, mathematics may obtain a "certain autonomy" as a living organism (Lakatos, 1976, p.146). Even though mathematics is a product of human mentality, it is regarded as independent of anything which can be associated with a psychological character. The purification of human activity from the things external to the content of this activity is the main motivation of Lakatos to look into the history of science. He identifies science as an activity whose historical evolution can be exposed primarily by internal factors (Lakatos, 1981, p.124). Since the external history is dealing with the psychological factors which have no direct effects, but rather some influences on the events which scientifically matters, it is assumed supplementary. The beliefs, character, authority of the scientist, or the socio-economic structure of the years when the scientist is working on her theory are all seen as secondary. The history of science is regarded as composed of a set of events which are elected and elucidated in a normative way (Lakatos, 1981, p.127). This normativity can only be given by the internal history which is articulated in sentences, like Popper's third world, which are the proclamations of "what to do" and "why to do it" (Hacking, 1981, p.139). The rivalry between the research programmes, their progressive and degenerative problemshifts, and the triumph of one over the other can only be the topics of the internal history. However, a transition between these internal and external histories is also possible. As oppose to Popper's view which approaches to a rival theory as an *external* catalyst, an attempt of falsification can turn into an *internal* factor for a research programme (Lakatos, 1981, p.118, footnote 29). If the programme manages to explain the anomaly rationally and benefited from it to foreseen a factual discovery, this externally introduced problem can gain an internal significance. This process of turning an external criticism into an internally valuable instance or hypothesis is basically what *heuristic* do.

2.2. Some Problems About Lakatos's Definition

Unfortunately, the analysis of the *heuristic* as a concept from the first and second hand literature is not enough to exhaust all of the ambiguities about its definition. Lakatos's methodology has still some obscure terms which put the status of the *heuristic* in jeopardy. One of the risks is a blurry line among three crucial elements of Lakatos's theory, which are hard-core, protective belt, and the *heuristic*. The uncertainty of the distinctions among the elements handicaps the resolution of a research programme into its theories. Since the research programmes are principally identified with their "characteristic hard-core which is stubbornly defended", "relatively more flexible protective belt" and "sophisticated problem-solving machinery", these three should be described as much distinctively as possible. However, it is also known that Lakatos allows programmes to include unsolved problems or undigested anomalies at any stage of the development of programmes in order to prevent them to be assumed born refuted (Lakatos, 1978, p.5). This methodological tolerance which is given to the research programmes for defeating their anomalies conclusively and so, increasing their chance of survival keeps the programmes to be in a permanent change. Unfortunately, this patience shown to the long procedures of resolving anomalies causes a slippery ground for the categorization of the theories under a specific programme. The criterion about which theories are included in the hard-core, which are in the *heuristic*, and which are in the protective belt and continue to keep its place becomes obscure. The elimination of any theory from the hard-core is not probable, but also Lakatos does not state any clear opinion against the possibility of the addition of new and compatible theories to the hard-core. Similarly, the decision maker for the future of the auxiliary assumptions in the protective belt is apparently the *heuristic*, but its place is not stable either. As a result of these gaps within the descriptions of basic elements of Lakatos's programme, it can be argued that *heuristic* can gain power in the later stages of the inquiry as much as a theory in the hard-core, i.e. the transformation of the principle about eliminating the equant. It was initially a heuristic for Copernicus's inquiry, but then turned into a hard-core theory in the heliocentric programme whose construction was completed long after him.

The liberation of anomalies can also cause a crisis about the demarcation principle between the scientific and the pseudo-scientific. This possibility is also considered by Lakatos and he tries to elaborate his methodology by some further distinctions to secure the demarcation. According to him, this liberty to the "inconsistent foundations" or the "occasional *ad hoc* moves" is given against the "old rationalist dream of fast-acting method for showing up falsehood or unprovenness" (Lakatos, 1978, p.149). These old dreamers, or falsificationists, try to defeat theories at once by putting forward a logical proof in the form of a single inconsistency or a single view of an experimental scientist who is convinced of the existence of an anomaly. These dreamers put the *crucial experiment* as a standard for evaluating theories.[11] This kind of experiments decides whether the old or the new theory will gain the superiority over the other by considering their success in predicting the results. If the theory is inconsistent with the result of the experiment, it fails and superseded by the other (Popper, 1962, pp.243-245). However, according to Lakatos, *crucial experiments* in Popper's sense do not exist (Lakatos, 1978, p.150). It is easier to see the inconsistency between a theory and an anticipated fact in falsificationist account, but also, it is trivial. To understand Lakatos's critic of Popper's theory, a sketch of his ideas is necessary. The crucial experiments are in the form of basic statements in Popper's theory. He takes his cue from Tarski's correspondence theory of truth and claims that describing the possible outcomes of a *crucial experiment* as basic statements is easy because their truth value can be decided by looking at whether they agree with facts (Popper, 1962, p.27, footnote 2). When two theories are confronted with each other through their incompatible

[11] Copernicus's case is an example to the absurdities that such reasoning can lead. If the crucial experiments are regarded as conclusive to decide whether a theory is scientifically defendable or not, Copernicus's heliocentric theory could not be regarded as scientific for almost three centuries. The crucial experiment of the Copernicus's theory was the observation of a stellar parallax, and it could not be documented until 1838. This reality entails that Copernicus's theory was not scientific until the observation of the German astronomer Friedrich Bessel in 1838, but after then it was regarded as scientifically valid (Lakatos, 1978, p.172).

predictions about the result of an experiment, this experiment is regarded as crucial for the decision which one of these rival theories will be corroborated. It is easy to see, in this picture, the conflict of the superseded theory's prediction with the result of the *crucial experiment*. Thus, the conflict-free theory continues to stand as not-refuted and keeps the title of "scientific" a bit longer. Lakatos shows the triviality in this method by pointing that the gain of the winner is just presenting a problem successfully, not an exhaustive victory over the other. For him, any theory, even it is false, can be preserved progressively for a long time, "with sufficient brilliance and some luck" (Lakatos, 1978, p.150). Not to leave keeping the title of scientific to chance, the "opening gambit" in the "game of science" should not be made by a hypothesis, but by a research programme (Lakatos, 1978, pp.149-50).

Lakatos makes another distinction to be cleared of all charges about weakening the border between the scientific and the pseudo-scientific. He puts some rules to decide which anomalies are liberated and which are not. What he basically argues is that if the programme performs a progressive problemshift, the tolerated anomaly does not threaten the scientific character of the programme. "As long as the problematic instances can be explained by content-increasing changes in the auxiliary hypotheses appended to it", the progressive character of the programme is taken for granted (Lakatos, 1978, p.41). Fundamentally, a research programme is assumed to experience a progressive problem-shift if the programme can manage to gain success in making novel predictions in addition to the necessary modifications in its protective belt. These modifications are required to solve the problem pointed out either by the internal mechanisms of the programme, such as self-recognized inconsistencies, or by external criticisms. If the programme satisfies this requirement, its empirical content grows, too, with the liberation of anomalies. However, when there is a long distance between what the theory foresees and what the results of tests say, theoretical explanation is assumed to fall behind the empirical growth. This kind of problem shift was named as degenerating (Lakatos, 1978, p.112). The problem here is the ambiguity of the criterion or criteria for deciding to what extent the degeneration of a progressing research remains tolerable. Lakatos's criterion necessitates clearer explanations about the determination of when the programme should be abandoned. The descriptive distinctions between the progressive and degenerating problem-shift are not enough. Some normative rules should be instructed by the methodology. According to Lakatos, the central concern of the scientist should not be whether a theory should be abandoned in the face of a counterexample. Rather, what makes a scientist a good scientist is the concern of how a research programme can be carried to the next stage (Larvor, 1998, p.57). Focusing on the advance, not on the refusal, is the key. However, defending the scientific by dedicating oneself to the progress seems a little naive. The scientific activity also requires "bad guys" who punish the intolerable behavior within the domain of science, which means producing pseudo-science. Unfortunately, Lakatos's theory is not successful in hunting the enemies of science as much as in keeping the scientifically valid theories on the right track.

2.3. A Contribution to Define the Heuristic: Questions

Questions can be raised to develop the construal of the notion of the *heuristic* at this point. The employment of series of questions as the means of constructing and evaluating theories can help Lakatos's theory to avoid some ambiguities pertaining to the concept of *heuristic*. For both of the problems mentioned above, a solution can be suggested by examining the questions made use of by individual inquiries. The transformation of questions through the different moments of the inquiry can be analyzed to illustrate the patterns of the inquirer's thinking. The up-to-now course of the inquiry can be reconstructed or its next steps can be estimated by measuring whether the questions can conform to varying stages of the inquiry, if they do not, how questions react to them. For instance, the questions can be exposed to some modifications like addition and elimination. Or, the inquiry can require completely new questions to bring a new perspective to the questioned phenomena. The formal and contextual alterations of the questions can be the keys of tracing back the inquirer's changing needs during the process of argumentation. The methods used in reorganizing questions can hint the inquirer's reasoning scheme, especially her way of dealing with problems and her success or failure to overcome them.

This question-based chase[12] for the inquirer's reasoning style is also fruitful for categorical distinctions that draw a line between the hard-core and the protective belt or between the progressive and degenerating. By the method of appraisal proposed by this chase, the way of posing questions to the "programmatically" problematic phenomenon, rather than the questioned phenomenon itself, becomes the standard for categories. For instance, while the questions about canceling the equant for saving Aristotelian principles are considered as the *heuristic*, the necessary arrangements to enable this elimination such as introducing a hierarchy between the spheres are treated as the auxiliary hypotheses of the Copernicus's programme. This inquiry initiated by a *heuristic* which questions the assumptions about the equant finally gives a birth to a theory about the Earth-in-motion, which is regarded as the hardcore. Even though the problems exemplified above belong to different categories in Lakatos's methodology, all of them are derived from the same inquiry which focuses on a single phenomenon called the equant. The decision about being progressive and degenerative can be treated similarly. This distinction can also be established by the questions. The domains where answers are tried to be found (for Copernicus, whether they are searched within astronomy or astrology) or the quality of answers (whether they are genuine or *ad hoc*) can give us some hints about the how-ness of the problem-shift. Therefore, chasing the questions of Copernicus as a case study can provide us a clearer ground for founding the categorical distinctions of Lakatos's methodology and a more explicit definition of the *heuristic*.

[12] This chase analogy is inspired by the title of a book called *The Great Copernicus Chase and Other Adventures in Astronomical History* (Gingerich, 1992).

CHAPTER 3

COPERNICUS AS THE CASE STUDY: THE PIONEER OF THE HELIOCENTRIC PROGRAMME

3.1. Some Ambiguities about the Definition of the Scientific Revolution

Within the history of science, the name of Copernicus is mentioned among the greatest figures leading epochal changes in our understanding of the world. He forced us to alter how to perceive our surroundings and "put on a new pair of spectacles"[13] to re-experience the things that we think we already know. What he did in astronomy evoked the questions about the verity of the traditional medieval Aristotelian cosmology which successfully maintained to rule for centuries. Even though it was challenged by a considerable amount of innovative opinions[14] and obliged to modify its archetypes about the mathematical representation of the universe,[15] Aristotelian cosmology managed to coexist with its rivals (Grant, 1996, pp.678-679). It resisted even to its Copernican rival for at least 144 years before it permanently perished.[16] Copernicus was the symbol of the systematic attacks against the scholastic cosmology within the 16th century, but the success of overthrowing it, which corresponds to a later date, should be attributed to

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13 This phrase is quoted by Shapin originally from Sir Herbert Butterfield (Shapin, 1996, p.2).

14 Controversies on voids, the possibility of the existence of other worlds, the plausibility of the daily axial rotation of the Earth, rejection of the celestial incorruptibility by some scholastics favoring Tycho's geoheliocentric system and Riccioli's assertions about an Earth more perfect than the Sun, etc. (Grant, 1996, pp.677-678).

15 Aristotle's system of purely concentric orbs was transformed into incorporation with Ptolemy's eccentric orbs.

16 This time length corresponds to the years between the publication date of two important books: Copernicus's *De revolutionibus* (1543) and Newton's *Principia* (1687) (Grant, 1996, p.679).

more people than solely him. His predecessors like Aristarchus,[17] Pyhtagoreans,[18] and the Arabic astronomers, especially Ibn al-Shatir,[19] should be counted here as the preludes of heliocentric cosmology. The contributions of Kepler, Galileo and Newton to scrutinize and justify the theories of Copernicus should be appreciated, too. The thing what we call as the "Copernican programme" or "heliocentric programme" was developed by the collective work of those historical figures. Nevertheless, the name of the Copernicus deserves to be distinguished from the other contributors. He was the one who was not contented with the mere mathematical representations and offered, for the first time, a real possibility for celestial physics (Gingerich, 1993, p.182). In addition to the mathematical representation of the universe, he gave physical explanations of how this enormous system was functioning (Gingerich, 1992, p.56). His ideas opened the doors of medieval scholasticism to a modern understanding of cosmology. Therefore, the title that we distinctly assume for Copernicus, at least in retrospective, should be "the pioneer" of the heliocentric programme.

Some characteristics of revolutionary periods can be inferred from the history in the light of the discussion above. First of all, revolutions do not happen within seconds. The historians of science hesitate to point a moment in history as the "scientific revolution" because most of the revolutions were neither started nor ended under the influence of a single and homogenous mode of change (Shapin, 1996, p.3). Rather, a wide range of scientific practices followed each other in a much or less continuous line

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[17] There were several references to Aristarchus in *De revolutionibus*, such as Book 3, chapters 2, 6, and 13 (Gingerich, 1993, p.186). However, these sections were crossed out before the publication (Gingerich, 1992, p.66).

[18] The Greek views about geokineticism which were cited by Copernicus from Aetius of Antioch (pseudo-Plutarch) and the "Letter from Lysis" can be analyzed (Gingerich, 1993, pp.186-188).

[19] His model was rediscovered in the late 1950s by E.S. Kennedy and one of his students at the American University of Beirut. Ibn-al Shatir's solution to eliminate the equant was very alike with Copernicus's solution in *Commentariolus*. There were also similarities between other Islamic astronomers (between the 8th and 14th centuries) who studied mostly on the corrections of Ptolemy's parameters used in observation. Their main motivation was to appropriately arrange pray-times and to determine the location of Mecca for any given place (Gingerich, 1992, p.47). The most preeminent names were Muhammed Al-Battani and Nasir al-Din al-Tusi from Maragha astronomers.

and contributed to the effort for improving our understanding the natural world in a specific fashion. This totality of successive events determined the characteristic of a revolution, and so, it cannot be portrayed by a discrete event or a singular person. This is also the case for the Copernican Revolution. Even though the revolutionary ideas were firstly introduced by Copernicus, what we call as the Copernican revolution is much more a body of knowledge including the theories of Kepler, Galileo, and Newton, too. Secondly, the revolutionary ideas might not be paid attention, or even heard, by their contemporaries. The impact of Copernicus's ideas when the manuscript was published in 1543 was not as strong as its content. Even his book, *De revolutionibus*, was known as "the book nobody read" (Gingerich, 2004, p.ix).[20] Also, the relatively "soft" reception of the book by the church, as compared to the Galileo's case, might be interpreted as that Copernicus's ideas were not understood comprehensively, and so, not regarded as a real threat.[21] Thirdly, and finally, the revolutionists are "chosen forebears" of a historical story which is written considering the purpose of the storyteller (Shapin, 1996, p.8). When we tell *this* instead of *that* story, we become the determiner of which practices or

[20] This claim originally belonged to Koestler. His book, *The Sleepwalkers*, had a chapter with this name under the section of "The System of Copernicus". He labels Copernicus's *De revolutionibus* in this way because of its very technical and dull style (Koestler, 1959, p.191). However, Gingerich proves that it was not the real case. Scholars were wrong to assume that only a handful of readers in the 16th century were familiar with the book (Gingerich, 1992, p.75). The secondhand annotations in the margins of the most copies disclose that since Copernicus's copy could not find a place in the ordinary university curriculum, a very wide network among the astronomy professors and their students were established for the exchange of remarks and notes.

[21] Osiander's introduction in which Copernicus's theories were treated as just hypothetical claims and the dedication of the book to the Pope also played a role in this soft reception, at least for a while. Although the manuscript was read and approved by the censors of the supreme council of the Inquisition before the first publication, and also inspected by theologians before reprinting, *De revolutionibus* was eventually censured in 1616 by the Congregation of the Index. The condemnation of Copernicanism by the Roman Catholic Church was based on the claim that Copernicus's heliocentric theory was conflicting with the passages in Sacred Scripture. However, it was not true. In one of the reviews asked from Augustinian theologian Didacus Stunica (1536-1598) in 1584, the reconciliation of Copernicus's ideas with the Scripture was approved. Stunica commented on the statement "But the Earth remains forever" in the Scripture and took attention to the context. The full phrase was "Generations will come, and generations will pass away, but the Earth remains forever". As Stunica pointed out, this statement was not entailing the assertion that the Earth was immobile, but rather emphasizing the existence of the Earth as one and the same during those ages in the past and the future. Unfortunately, Stunica's comments were also censured in1616 (Gassendi & Thill, 2002, pp.271-275).

characters will be depicted as central to the revolution. In all historical stories, there is little "us" incepted to the way of telling these stories. Especially the stories about scientific revolutions are reconstructed by the changes that "we" think led on to specific properties of the present which "we" are interested in for some reason (Shapin, 1996, p.10). The story cannot be fully purified from the subjective point of view because what we choose to tell about the past unavoidably represents our present-day-interests. The same instances of subjective choice can be seen in the entitlement of Copernicus as "the pioneer of the heliocentric programme". Even though similar ideas had been discussed by his predecessors, he was labeled as the revolutionist and advertised as the forefather of the heliocentric cosmos. Of course, those choices were not wholly the products of the historian's construct. However, the way of picturing the socio-cultural context in which the mentioned revolution was born and spread bear the traces of the subject. This is what is also called as "the historian's predicament" (Shapin, 1996, p.10).

Some may think that a historical essay which omits the social aspects of a revolution is read more easily because there is no need to struggle with the historian's dilemma. Also, such an essay may be counted as a more credible source because of not comparing apples to oranges. The separation of the social from the scientific can be seen as necessary for telling a scientifically defendable story. A similar demarcation principle may be adopted for the dynamics of the scientific activity, too, such as the processes of discovery and justification. While the discovery is amount to successful moments of an inquiry in revealing facts about the nature of the questioned phenomena, the justification means processing these empirical facts within a consistent narration. A division between the frameworks of these two can be defended for weighing the scientific quality of theories properly. By the disassociation of the context of justification from the context of discovery, what the theory is about can be figured out without a bias. In this separation, the former aims to disclose "objective relations" such as the derivability of the conclusion from the premises of an argument, whereas the latter explains the "subjective way" of seeing these relations such as *a-ha* moments of the scientist

(Reichenbach, 1938, pp.36-37). Since the process of exploring things cannot be dissociated from the background of the scientist, the rationale behind discovery is believed not to be validated in the realm of science. If this cannot be handled, and if the objects of *the psychology of scientific discovery* are confused with *the logic of science*, some misinterpretations may arise about how science proceeds (Reichenbach, 1938, p.36). For instance, the socioeconomic history of a scientist can be used for or against the trustworthiness of her ideas, and this misjudgment can cause the overvaluation or undervaluation of her theory.

However, some also may argue against this demarcation and advocate the inseparability of "intellectual factors" and "social factors" (Shapin, 1996, p.9). As oppose to the views sketched above, an intention for unifying all aspects of the scientific activity can be supported, too. For a full-fledged evaluation of theories, it can be argued that the influences of socio-economic conjecture on science, the forms of scientific organizations, and the social consequences of the scientific activity have to be considered, too. It is true that the information gained from the description of the scientist as a social being do not give solid evidences as the method or arguments of the scientist can give. But still, these are necessary for knowing what is going on in the scientist's laboratory in every respect. "There is as much society inside the scientist's laboratory, and internal to the development of scientific knowledge, as there is outside" (Shapin, 1996, p.10). For the summary of the project unifying the context of discovery and justification, we should give ear to Shapin:

> If science is to be understood as historically situated and in its collective aspect (i.e., sociologically), then that understanding should encompass all aspects of science, its ideas and practices no less than its institutional forms and social uses. Anyone who wants to represent science sociologically cannot simply set aside the body of what the relevant practitioners *knew* and how they went about obtaining that knowledge. Rather, the task for the sociologically minded historian is to display knowledge making and knowledge holding as *social processes.* (Shapin, 1996, p.9)

I describe the "knowledge making" as the totality of the circumstances which enables the inquirer to discover a theory and the "knowledge holding" as the justifiable content of this theory. When these two are hold together and analyzed in parallel with each other, the process of inquiry can be clarified from the beginning to the end. The circumstances giving rise to the construction of a research programme can be processed to be useful for its justification. How to make knowledge can give us some tips about how to hold it. The research programmes can be guided for their improvement in problem-solving by stretching the pattern of discovery out to the method of justification.

To clarify what I am planning to do with this possibility of unifying the contexts of discovery and justification, Gingerich's chase after the annotations on Copernicus's *De revolutionibus* can be given as an example. He searched the copies of the book all around the world in order to investigate any marginal annotations for hints about how the book was reviewed in past centuries (Gingerich, 1992, p.83). If the project that I am currently busy with is a two-phased study, what Gingerich did is the second phase, which is developing a method for appraising Copernicus's theory by referring to the notes of the others on his book. What I will do, which is the first phase, is investigating how Copernicus discovered his theory through the references to his own questions. They either were asked by Copernicus himself and took place in his manuscripts or *might* be asked by him but actually formulated by the scholars commenting on his works. While I am analyzing Copernicus's theory through such questions, I will benefit from a kind of "incepted" story telling. I will select the questions which are crucial, I think, to picture his pattern of thinking. But before this, I will give a biography of his life considering the developments which might lead him to engage with logic and science in general, and then, more specifically with cosmology.

3.2. The Life of Copernicus

3.2.1. Origins

Nicolaus Copernicus was born on 19 February 1473 in Thorun (hereafter, Torun), Borussia (Prussia).[22] Torun had a large town market in those years and known as "the inner port of Poland" (Gassendi & Thill, 2002, p.6). The city lies on the bank of the Vistula, the main Polish river. His childhood and early youth were spent along this river, mostly in Torun and Cracow. He was brought into the world as the youngest child of a German family, but he subjected to the Polish crown. Torun was declared as a free city after the Second Treaty signed between German and Polish parties of the Thirteen Years War in 1466. Just as Danzig, the Varmian bishopric and others, Culm (the bishopric of Chelmno) which is the hometown of Copernicus came under the Polish crown after then. Therefore, his mother, Barbara, gave birth to him in a real Polish town.

The German parents of Copernicus, Nicolaus, Sr., and Barbara, were loyal to the Vatican and family circle involved many of clergymen. In religious matters, Copernicans were traditionalist. Nevertheless, they were a side during the uprisings in Prussian cities which defended their independence from the Teutonic Order of the Knights of the Cross. They were active supporters of the Prussian Alliance which consisted of citizens who were opposed to the Teutonic Knights (Gassendi & Thill, 2002, p.55). The maternal grandfather of Copernicus, Lucas the elder, was a delegate of the Alliance and represented Torun in a meeting held in Graudenz (Grudziadz) in 1453. He also attended the fights between the Alliance and the Teutonic Knights, and was wounded. Copernicus's father, Nicolaus the elder, also gave financial support to the Alliance for taking back the castle of Schwetz (Swiece) in 1461-1462. In this respect,

[22] This date, according to Julian calendar, is the mostly agreed one among Copernican scholars. However, there are still some alternatives about Copernicus's birth such as the 10th of February 1473 (Caspar Peucer) and 4th of February 1473 (Johannes Gartze). This work will remain loyal to the dates within Gassendi's *The Life of Copernicus*, unless indicated otherwise.
In addition to this, Gassendi avoided introducing the exact birth time of Copernicus by specifying which minute he was born. As a believer of the exact sciences, Gassendi aimed to limit the enthusiasm of astrologers to draw Copernicus's theme (Gassendi & Thill, 2002, p.13).

they were politically reformist. One of the difficulties that Copernicus's maternal side, the Watzenrodes, had to face as a result of their political orientation was the stonewall in front of the advance in the career of the uncle Lucas, Lucas the younger. He would never become the archbishop of Marienburg because of the Watzenrodes's opposition to the Teutonic Knights. This complex position of Copernicus's family is supposed to be one of the reasons of his distance kept from the business of bishopric or the chapter, except few vacancies he was invited (Gassendi & Thill, 2002, p.55).

Copernicus's birth also corresponds to a historically significant period. The year of 1473 was the boundary between the Middle Ages and the Modern Times (Gassendi & Thill, 2002, p.7). This shift in history was mainly represented by two momentous events; the overthrow of the eastern part of the Roman Empire in Constantinople by Ottomans in 1453 and landing on Bahamas, also known as the New World, accomplished by the crew of Christopher Colombus in 1492. Copernicus's birth literally stood in the middle of these dates. His life, education, and works also resembled this switch in history with all its challenges and innovations clashing between the antiquity and the modernity.

Copernicus's father, Nicolaus, Sr. (circa 1420- 1483),[23] was a businessman who bought large quantities of copper from the south and sold them to the merchants from Danzig. The probable origin of the last name, Copernicus, which comes from the village Köppernig where his ancestors migrated, supports the assumption that his father's profession was trading copper. In Latin, the root of the name is "cuprum" which means "copper" and indicates the presence of mines of copper close by the region (Gassendi & Thill, 2002, pp.17-18). Copernicus's mother, Barbara, was the second child of a wealthy family of merchants, Watzenrodia (Watzenrode) family of Torun. Her birthdate is unknown, but her death is supposed between 1495 and 1507. She had an older sister,

[23] As opposed to what is repeatedly said, the death of Copernicus's father could not be necessarily in 1483 (Gassendi & Thill, 2002, p.20). Gassendi claimed that it was between 18 July 1483 and 19 August 1485 with respect to the records numbered as 18 and 19 in of Marian Biskup's *Regesta Copernicana*.

Christina, and a younger brother, Lucas. Later, the uncle Lucas (1447-1512) also took guardianship of Copernicus after his father's death.[24]

Copernicus had an older brother, Andreas (circa 1470-1518) and two sisters, Catherina, Jr., and Barbara, Jr. The dates of birth of two sisters are unknown. Andreas was the family member with who Copernicus spent most of his time. Copernican brothers were together in their early education in Torun. They went to Bologna together for the first four years of their education in Italy and also returned back to Poland together in 1501. One of the biggest despair that Copernicus experienced in his life was his incompetency to cure the illness of Andreas. The disease, leprosy, appeared circa 1508 and it eventually caused his death (Gassendi & Thill, 2002, p.71).[25] Even though Copernicus was regarded as a gifted doctor that he was referred to as "another Aesculapius"[26] which is the name of the god of medicine in Greek mythology, Copernicus could not manage to heal Andreas.

The nationality of Copernicus is a subject of discussion. It is not known for sure whether he is German or Polish or having Slav blood in his veins but it is mostly agreed that his mother tongue was German (Gassendi & Thill, 2002, p.19). He also learned Polish and, at an early age, Latin which was the language of science, traders, travellers

[24] Although it is unlikely, another possibility for the guardianship of Copernicus might be the husband of aunt Christina, Tileman von Allen. He was the mayor of Torun from 1473 till his death in 1499. This possibility was originally proposed in Leopold Prowe's *Nicalous Copernicus, II.* He took attention to the figure on the signet ring of Andreas Copernicus. It was characterizing the arms of the von Allen family. However, twelve children that Tileman were responsible to bring up and his busy job were weakening this claim as also Prowe acknowledged. More unlikely, the third possibility might be Johann Peckan who was the half-brother of Copernicus's mother from the first marriage of the grandmother Kethe (Catherina) with Henrich Peckan (Gassendi & Thill, 2002, pp.24-25).

[25] There is a disagreement about what the disease that Andreas suffered from was. It is also probable that he had syphilis. This new disease of the early 16th century was said to be imported from the New World by the sailors of Columbus and the time period of Andreas's illness was historically matching with the outbreak (Gassendi & Thill, 2002, p.72). According to Gassendi, the first possibility, leprocy, was more adequate because there are documents confirming that Andreas was excluded from the chapter because of his contagious disease called "lepra" (Gassendi & Thill, 2002, p.73).

[26] This name was attributed to Copernicus by one of his fellow canons, Tiedemann Geise, in one of his letters to Copernicus (Gassendi & Thill, 2002, p.64).

and daily prayers. Copernicus's family was very rich and it is likely that his mother was helped by two persons and a wet nurse to take care of her children in addition to two servants resided in the family house (Gassendi & Thill, 2002, p.19). The family sold the old house in which Copernicus was born when he was seven, and moved to a larger house in the city center in order to ease the family meetings with aunt Christina and her children that she raised with his husband, the mayor Tileman von Allen (Gassendi & Thill, 2002, p.20).

3.2.2. Education

About the early education of Copernicus, there are no known documents that have been preserved. It is supposed to have taken place between the years of 1480 and 1491. The average period at this time of study in early education was eight years. Since the starting date of Copernicus's education is not definite, two possible date ranges are proposed: either between 1480 and 1488 or 1483 and 1491. The latter range is mostly agreed because it is more plausible for Copernicus to start his education after his uncle, Lucas, took Copernicus's guardianship (Goddu, 2010, p.11). Nevertheless, the most likely school that Copernican brothers studied is parochial school of St. Johann (John) in the old city of Torun (Goddu, 2010, p.8). The general curriculum of the school was built upon repetition and memorization. Additionally, arithmetic and geography were taught because Torun was a commercial center (Goddu, 2010, p.9). When Copernicus completed his education and became able to enter the university, he could read and write in Latin, knew grammar, was familiar with classical poets and authors, was acquainted to the basic principles of logic, and, learned the theory of ratios: arithmetic, geometry and music (Goddu, 2010, p.13). If he started his education three years earlier rather than in 1483, he might take a cathedral education in Chelmno or Wladislaw probably between 1488 and 1491. Following this conditional claim, he might be trained in astronomy, practicing music, scholastic philosophy and biblical theology of a humanistic strain (Goddu, 2010, p.11). However, being educated in a school in Chelmno is not a sound premise because if this had been true, then Copernican brothers would have had to leave their mother and cousins (Gassendi & Thill, 2002, p.24). Since there is no evidence which indicates the separation of Copernican brothers from the family in their early education, it is more plausible to accept that they were the students of the parish school of St. Johann in Torun. As also Leopold Prowe points out in *Nicolaus Coppernicus, I*, the uncle Lucas was also connected to this school (Prowe, 1967, p.111). He participated to some regulations of the educational system of Torun as the Ludimagister of the city, a teacher of the Roman educational system instructing some basic reading and writing skills to the students at the age of six till ten.

Copernicus's high education began in 1491 with his entrance to the University of Cracow. He studied liberal arts, but left the university without a degree. Scholars principally share the same idea which is that he has been attending to the classes in Cracow regularly until 1495 (Goddu, 2010, p.20). In the last quarter of the 15th century, Cracow was under the influence of an eclectic tradition composed of several tenets and this assortment in teaching subjects and styles also dominated the atmosphere in the university. The University of Cracow was endeavoring to harmonize nominalist tradition with logic of consequences -the theory of inferential operations between propositions- and demonstrative syllogism (Goddu, 2010, p.74). The students were instructed in several major medieval traditions. The fundamental skills that Copernicus gained there were practical training in astronomy and some intellectual habits such as "tools of thinking, writing techniques of expression and argumentation" (Goddu, 2010, p.16). It should be noted that these qualifications which were acquired by mainly elementary philosophy courses in the university were too raw and not enough qualified to play a major role in the discovery of Copernicus's model of universe. Since his theory presented in the *Commentariolus* formalized probably between the 1509 and 1510,[27] the

[27] Since there is no observation recorded before 1509 in *De revolutionibus,* it is highly probable that Copernicus had not yet decided to construct a major work in astronomy at that time. Otherwise, he would

knowledge that he accumulated during the years in early 1490s at the university should not be overvalued. It would be more plausible not searching for a direct link between the courses that he took in Cracow and his preparation for his heliocentric theory. But rather, the gains of the university education and the intellectual climate should be delimited to a bunch of collectible skills that helped Copernicus remarkably to present his theory to the scientific community and amateur readers (Goddu, 2010, pp.16-17).

Within the years of Copernicus in Cracow, essentially three major professors were giving lectures in the university. They were John of Glogovia (1445-1507), Albert of Brudzeno (1445-1495) and James of Gostynin (1454-1506). It is possible for Copernicus to attend the lectures of these professors if he did not create a personal program in academy, but rather preferred to follow prescribed version of the curriculum (Goddu, 2010, p.47). John was a logician and giving lectures on Aristotelian logic. The course of logic in the university consisted of studying propositions, meaning of the composites within a proposition, preparation to the study of syllogistics (prior analytics), demonstrations (posterior analytics) and dialectical arguments (topics) with the introduction of categories. The main textbook of the course was Peter's of Spain *Tractatus* (the 13th century), by then known as the *Summulae logicales (Summaries of Logic)*, on Aristotle's logic depending on Boethius's interpretation (Goddu, 2010, pp.53-54).[28]

The original contribution of John to his students might be teaching them in the methods to reject paradoxical entailment rules (Goddu, 2010, p.75). Originally, the rules of paradoxical entailment narrow down the consequences derived from an argument

require the observations before 1509 to check the validity of his tables for those times, too. It is also highly likely for Copernicus to finish writing *Commentariolus* in 1510 before or shortly after he moved to Frombork permanently (Goddu, 2010, p.270).

[28] Michael of Biestrzykowa also instructed students at the University of Cracow (1487-1504) in medieval logic with the textbook of Peter of Spain. Another fellow of the University of Cracow was Michael Falkener of Wroclaw. He compiled a handbook about argumentation called '*De symategorematibus*' to instruct in his classes. All the lectures and exercises of logic taught in the university were mostly in practical manner (Goddu, 2010, pp.74-75).

which contains contradicting propositions into two possibilities, which are: i) From the impossible, anything follows, and ii) The necessary follows from anything. The logicians adopting these rules were defending that these two consequences have to be regarded as logically acceptable because of their formally valid structure. However, John rejected the validity of such conclusions required by the rules of paradoxical entailment and endeavored to reveal the illogical nature of making any inference from a paradox. His anchor point was that formal consequences ought to be grasped with the meaning of their antecedent and so, this requisite could not be provided when the antecedent is impossible (Goddu, 2010, p.77). More specifically, his objection to the first rule was "an impossible consequent is no included in the meaning of an impossible antecedent"[29] and to the second was "between an impossible consequent and antecedent, there cannot be a relation of cause and effect" (Goddu, 2010, p.75). John's proposal here was establishing a relation between antecedent and consequent much weaker than causality. He and some other professors at Cracow like Michael Falkener suggested a natural relationship between those two ruled by intrinsic topics (Goddu, 2010, p.84). The main criterion of such a relationship was that a good consequence which can be traced through non-false propositions must not allow the entry of anything extraneous or irrelevant.

Seeing that the truth of the antecedent cannot be separated from the truth of the consequent is the key of John's standpoint regarding paradoxical entailment. If Copernicus took logic courses from John, his opinions on this subject might be shared with his students including Copernicus. It is also known that he read and commentated on Ficino's translation of Plato's *Parmenides* (Goddu, 2010, p.314). The method used in the dialogue of Plato was called as the dialectical inquiry and run by testing each main theory or hypothesis in terms of the consistency between them and their consequences. When this inquiry finished, the hypotheses that the ancients believed to be true became

[29] John of Glogovia accepted the truth of the first rule if and only if the distinction between formal and material consequences was indicated clearly. If a consequence that appeared valid had not any real instance invalidating it, this consequence could not be assumed material. Therefore, even if the antecedent was impossible, the consequence could be formally valid (Goddu, 2010, p.79).

separated from the ones they assumed to be true for the sake of "saving the phenomena" (Goddu, 2010, pp.315-317). If a hypothesis that was necessary or essential was omitted or something extraneous or wholly irrelevant was added to the theory, this method could show the inconsistency. In the construction of his heliocentric theory, Copernicus also used a similar method to reveal the inconsistency between the geocentric-geostatic theory and its consequences such as the ill-explained phenomenon of retrogression (Copernicus, 1992, preface, p.4). According to Copernicus, the calculations that were made by means of the eccentrics and epicycles were not enough alone to explain the non-uniform motions of heavenly bodies. While an eccentric meant a circle whose center was a point but not the Earth, an epicycle was designed to move on the eccentric and carry planets. Furthermore, introducing an equant as Ptolemy did was not helping but rather complicating the explanation of the retrograde motion. Since the equant was defining the uniformity with a reference to another center different than the Earth, this tool was violating the axiom of uniform motion. The method of Copernicus to find an alternative hypothesis to explain the retrogression required to have a mobile Earth and to eliminate the geostatic theory. His formulation was a result of a dialectical investigation which questioned the validity of the relation between the fundamental hypotheses of geocentricism (i.e., the immobility and the centricity of the Earth) and their consequences (i.e., the violation of the principle of uniform and circular motion). Copernicus's attempt to compare the character of the consequences with this of the antecedents can be considered as an example of the dialectic inquiry which was performed by the ancients and inspired John, too (Goddu, 2010, p.85, p.317).

Other professors like Albert of Brudzewo and James of Gostynin might have minor influences on Copernicus, of course, if he attended their classes. Albert was an astronomer. His works were on "ancient rules of the uniform and circular motions of the celestial spheres" and he was also cynical about Ptolemy's astronomy (Goddu, 2010, p.37, p.49). Although there is no direct reference to Albert, an acquaintance to Albert's *Commentariolum* could be intuited in Copernicus's *De revolutionibus* (Goddu, 2010, p.37). James of Gostynin, who was originally a theologian, might also teach Copernicus Aristotelian philosophy. There were two other figures that helped or inspired Copernicus in his studies out of the university courses. The first one is a teacher of poetry and an amateur geographer, Lawrence Corvinus (1446-1527). He was a supporter of Lutheranism and advocator of Italian Humanism. He was interested in Platonism and Neoplatonism like Copernicus (Goddu, 2010, p.141). Corvinus supported Copernicus to prepare his first book, a Latin translation of a letter series on morals (Goddu, 2010, pp.43-44).[30] The other friend from Cracow was Bernard Wapowski (1470-1535). He was a canon closely interested in geography. Copernicus's evaluation of John Werner's treatise was written by the encouragement of Wapowski in 1524.[31] His opinions inspired Copernicus to preserve Ptolemy's model against Werner (Goddu, 2010, p.47).

Apart from medieval teaching of logic, there were two other main modules in Liberal Arts at the University of Cracow, which were natural philosophy and humanism with basics of astronomy. The major issue in natural philosophy was the cosmology of Aristotle. The introductory text book of the course was an anonymous compilation in the form of questions on Aristotle's '*Physics', 'De caelo', 'De generatione et corruptione'* and *'Meteorologica'*. It was written within the Thomistic tradition. This philosophical school was known for the challenging questions and commentaries of Saint Thomas Aquinas (1225-1274) on Aristotle and was assumed for many years to be the authority for presenting the philosophical and theological perspective of the Catholic Church. The Thomistic tradition was widespread in Cracow between 1464 and 1474 (Goddu, 2010,

[30] In 1509, Copernicus published his first book called *'Teophilactus'* in Cracow by Johann Haller. It consisted of eighty-five small letters written fictitiously about morality. The book was a translation of the letters which were originally written in Greek, but Copernicus added some parts to the beginning of it. It was starting with a fictitious letter of Copernicus to his uncle Lucas and followed by 116 verses composed by Lawrence Corvinus (Gassendi & Thill, 2002, pp.58-59).

[31] The evaluation, also known as the *Letter against Werner*, was about the motion of the eight sphere. Johann Werner (1468-1522) was a priest advocating secularism and interested in astronomy and mathematics. This letter was about two errors of Werner, which were pointed out by Copernicus. These were firstly, the argument against the precession of equinoxes and secondly, the belief about the uniform motion of the fixed stars. The former was conflicting with the ancients, and the latter with Ptolemy (Gassendi & Thill, 2002, pp.142-143).

p.100). The questions in the introductory book of the city university were about the nature and the natural place, the celestial spheres and the celestial matter, the relation between the mathematics and the natural philosophy, the dialectical topics specific to natural philosophy, the infinite, the void, and the impetus (Goddu, 2010, pp.101-114).

It should be emphasized here that the natural philosophers of the time were not firm followers of the same cosmological opinions. The ways of presenting central notions of the natural philosophy mostly remained loyal to the traditional Aristotelian terminology, but they also entertained some “innovative tendencies” (Grant, 1996, p.676). The new ideas or hypotheses which did not pose a direct threat to the basics of traditional Aristotelian cosmology were welcomed warmly to the scientific discussions. Still, a full transparency in the customary scholastic literature could not be managed when the case was commenting on big authorities. One of the examples carrying the signs of discomfort due to the dominance of Aristotelian terminology in cosmology was *questiones.* They were different from the commentaries which were trying to expose the works of Aristotle section-by-section. These treatises in the form of questions were much more argumentative and so, became broadly used in medieval universities by the late 13th and the early 14th centuries (Grant, 1996, p.23). Jean Bridan, Aegidius Romanus, Thomas Aquinas, Petrus de Alvernia, Albertus Magnus were some of the figures adopting this writing style. The main sequences of this literary form can be described as follows: posing a question depending on sections or passages, evaluating possible answers by presenting their pros and cons, and finally, ending up with a satisfactory solution (Weisheipl, 1964, p.154). This pedagogically successful form of the treatises was performed primarily orally, but some of their written forms affiliated with the names of renowned masters managed to survive as question treatises, or *questiones* (Grant, 1996, p.24).

Cracow was not independent of this variety in teaching medieval cosmology. Most of the professors in city university were faithful to Aristotelian doctrine even though some of them adapted non-Aristotelian perspective about subtopics like the place of the universe, void, and the theory of impetus (Goddu, 2010, p.99).[32] Copernicus's view of Aristotle was formed in the second half of the 1490s in Cracow with the help of the lessons taught by professors specialized in Aristotle's works. The general orientation of those professors can be outlined as "adapting thoughts inconvenient to Aristotle and turning them into Aristotelian principles" (Goddu, 2010, p.133). For instance; Averroes's critic of Ptolemaic astronomy was known in Cracow through Aristotle's *Metaphysics, Book XII,* which briefly mentions Averroes's homocentric argument against Ptolemy's eccentric-epicyclical model of universe (Goddu, 2010, p.134). Other evidence to Copernicus's acquaintance with Aristotle's texts can be given from the passages in *De revolutionibus.* Some sentences which seem as though they were written from memory remarkably resemble Aristotle's views.[33] After 1503, Copernicus began to have an acquaintance to assertions favoring Plato, as well (Goddu, 2010, p.97). In 1508, his earliest conclusions about the contemporary approaches to astronomy from ancient to modern and possible solutions on them were refined. In 1510, his own philosophy on cosmology was substantially developed. According to Mieczyslaw Markowski's interpretation in *Filozofia przyrody*, the education of Aristotelian natural philosophy in Cracow was authentic and this education style managed to encourage Copernicus to embrace the transition in astronomy during those days to a modern understanding of celestial mechanics by preserving his ties with Aristotelian tradition.[34] The courses on natural philosophy which Copernicus had probably attended during the years spent in

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[32] For instance, Albert of Saxony was critical about Aristotelian doctrine. Albert was positing impetus in the form of an accidental gravity like his Parisian colleagues but he was referring it as a violent motion (Goddu, 2010, pp.129-132). Another figure commenting on Aristotle's *Metaphysics* antithetically was John of Glogovia whose opinions were mostly shared by Copernicus, too. John claimed that Sun was standing "in the middle… as a king" and all the motions of the planets were related to the motion of the Sun (Goddu, 2010, p.133).

[33] To support this claim, Goddu takes attention to some passages from Polish historian Aleksander Ludwik Birkenmajer's *Études* (p.134).

[34] Markowski's monograph was written in Polish and completely disregarded outside of Poland (Goddu, 2010, p.94-95, footnote 12, footnote 13). There is no translation into any western European language. So, the only reference can be put here for his thoughts are these quoted by Goddu. In his references, these ideas of Markowski corresponds to the page 152 and 170 in his *Filozofia przyrody* (Goddu, 2010, p.97).

the University of Cracow might hearten him later to make further readings on the contemporary interpreters of Aristotelian tradition. For instance; the motive of Copernicus to attribute terrestrial properties to celestial bodies in his novel theory was very likely post-university readings about Platonic and Stoic views on elements (Goddu, 2010, p.95).

The University of Cracow also gained a reputation in training scholars in astronomy and astrology both theoretically and practically (Goddu, 2010, p.137). The growing interest to the humane studies in general and the enrichment in the areas of specialization of the university concerning the natural philosophy in particular is deeply owed to the Italian Renaissance and its humanistic influence on the intellectuals of Cracow (Goddu, 2010, p.137-145). In the late 14^{th} and early 15^{th} century, the intellectual and cultural atmosphere was refreshed as a result of political expansions and commercial growth. The rise of the landed gentry which was the middle class of the old regime altered the vision of the universities in Polish Kingdom in favor of the art and the literature. The merchants became the new grand of Cracow and assisted the university (Goddu, 2010, p.137). Renaissance humanism was brought in Cracow through the contact of students, especially studying law in Italian Universities, and also with the officials in Rome and the participation of Polish representatives to the Church Councils taking place in Countance and Basel (Goddu, 2010, pp.138-139).

There were many figures and societies established in Poland in line with the humanistic tradition. Gregory of Sanok (1406-1477), Jan Ostroróg (1436-1501) and Lawrence Corvinus (1402-1527) were the leading characters of Polish humanism (Goddu, 2010, pp.138-141). Gregory was an archbishop and defending the humanistic education against scholastic style. Jan had a degree in law in Bologna and was supporting Polish nationalism and secularism. Lawrence, a friend of Copernicus, taught scholastic and classical works at the University of Cracow, but also was one of the founders of humanistic studies in the university. In 1480s, a Renaissance society was formed in Cracow by a group of locals with the aim of increasing knowledge about humane letters. By impact of printing as well as Renaissance humanism, most of the faculties initiated to collect books and many of these collections were eventually possessed by Jagiellonian Library (Goddu, 2010, pp.141-142). The effects of Italian humanism on mathematical disciplines such as astronomy and geography could not be seen explicitly in Cracow until the 16th century except some individual interests (Goddu, 2010, p.142).[35]

What Copernicus received from his professors about astronomy in Cracow was the acquaintance to two basic reviews of Aristotle, *De sphere* and *Theorica planetarum*, and some knowledge about tables, canons and instruments. *De sphere* was a book of John of Sacrobosco in the form of an introduction in the matter of spherical astronomy. The book was broadly covering definitions about the essential characters of celestial spheres. In addition to this, the rules of perfect and uniform motion were explained. Some philosophically relevant questions about the compatibility of observational results with the geocentric models were also introduced (Goddu, 2010, p.147). Therefore, the book was rather qualitative than being quantitative. *Theorica planetarum* was giving an account on planetary motions.[36] The intention of the book was accommodating Ptolemy's mathematical model with Aristotle's concentric cosmology (Goddu, 2010, p.148). Additionally, Copernicus had the famous Latin table, Alfonsine Tables, which based on comparison rather than observation apart from those in *Almagest* (Goddu, 2010, p.142). Exercises within the tables were textual and the instructions of canons were benefited for further calculations like the equation of the center. Copernicus had also a copy of Johannes Bianchini's tables in Cracow. Even though it is possible, there is no evidence that Copernicus constructed or used any astronomical instruments. His

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[35] There were some administrators around Copernicus interested in astronomy both as an amateur like the rector Conrad Gesselen (1435-1450) and with academic concerns like the rector John Wohlgemuth (1460s). While Conrad was dealing with astronomical tables, John was writing scholarly about astronomy and had a work titled *'Trilogium animae'* (Goddu, 2010, pp.9-10).

[36] There were at least two versions of *Theorica*; *Theorica planetarym gerardi* and *Theorica* written by Campanus of Novara. While the former was published several times in the 15th and the 16th centuries, the latter was just acknowledged in manuscript (Goddu, 2010, pp.147-148).

knowledge on instruments was likely limited to the descriptions and instructions on how-to-make (Goddu, 2010, p.151).[37]

One of the reasons why Copernicus left Cracow without any degree might be that his goal of being a doctor did not require getting a bachelor degree from an intermediary university like Cracow. Wasting time and money, and also being obliged to give an exam for having degree could not be welcomed among upper-class burghers as Copernican brothers (Gassendi & Thill, 2002, pp.28-29). Another reason might be that Copernicus wanted to continue his education in a more prestigious university. Back then, it was fashionable that students from relatively small countries started their study at a neighboring university and then finished their education at a more distinguished university, particularly one of those in Italy. Like uncle Lucas who earned the grade of Magister from the university of Cologne after leaving Cracow without a degree, Copernicus also might choose this path (Gassendi & Thill, 2002, p.29).[38] A third reason and also the intensifier of the second might be the outdated curriculum of the faculty of arts and the general inability of the university staff to catch up with the recent developments in mathematics and in explaining the nature. Even in Cracow, the employment of the scientists in such faculties was not favored and they were advised to

[37] Since no observation was made by Copernicus earlier than 1497 when he was in Bologna, the probability of using devices for astronomical observations was very low for his days in Cracow (Goddu, 2010, p.152).

[38] There can also be another reason why Copernicus could not earn a degree at the University of Cracow, but it is less credible. Edward Rosen points this probability and suggests that it would be that Copernicus had not enough time to get a degree. At those times, the necessary time for having a diploma was standardized by the Vatican with other issues regarding universities. At the end of the forth semester, students could achieve the grade of bachelor and eight semesters were asked for the grade of magister (master) at minimum. Accordingly, Copernicus spent more than the necessary time in the university and still left there without a degree (Gassendi & Thill, 2002, p.28). The possibility of being not able to overcome the courses that he attended during his years in Cracow and so, failing in getting a degree was not even worth to consider for Gassendi. Copernicus's magnum opus, *De revolutionibus*, and the level of mathematical explanations in this book invalidate the assumed laziness of him (Gassendi & Thill, 2002, p.27).

continue their career in another intellectual environment.[39] Therefore, it is plausible to think that Copernicus chose to maintain his education in the cradle of Renaissance humanism, Italy, where the amateur questions provoked in Cracow could find advanced answers (Goddu, 2010, p.166).

3.2.3. Years Out of the Hometown

After Copernicus departed Cracow, he returned to Torun and stayed there for a while.[40] In 1495, a vacancy for benefice in Warmia (Varmia) occurred. The bishop of Varmia was Copernicus's uncle, Lucas, and wished Copernicus to be elected for the position becoming absent after the death of the previous canon.[41] Studying in law, sooner or later, was one of the essential conditions of becoming a canon. Since Copernicus preferred to study in Bologna rather than staying in Cracow, he had to find a common way for benefiting from the benefice and studying in a better university at the same time (Goddu, 2010, p.19). According to the statute, a canon could benefit from the income of canonry even if he would not actively performing his service, if his excuse was studying towards a degree one of the following fields; theology, law or medicine (Goddu, 2010, pp.21-22). Thanks to this rule, he could accept the vacancy by affirming that he would study medicine at the University of Padua for two years. With this arrangement, Copernicus managed to be one step closer to his plan to study in Italy.

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[39] Originally taken from Pedersen's *Tradition and Innovation*, 469-472, and cited by Goddu in the 100th footnote (Goddu, 2010, p.166).

[40] There are some other speculations about where Copernicus was between 1495 and 1496. Some believe that he travelled and visited some German universities, especially the one in Nürnberg, to confer with mathematicians and to examine sources pertaining to Peurbach and Regiomontanus. However, none of them have been proved (Goddu, 2010, p.172).

[41] Because of the financial decline shared by Watzenrode and Copernicus families in 1480s after the death of Nicolaus, Sr., uncle Lucas decided the future of Copernican brothers beforehand. He wanted them to enter the service of the church and wanted to arrange a secured job for them (Goddu, 2010, pp.18-19).

Unfortunately, some complications arouse in payment of the canonry's income and Copernicus could not enjoy this financial support until 1497 (Gassendi & Thill, 2002, p.36). His plans to travel to Italy for studying medicine voluntarily and law compulsorily were suspended. Since he also knew that having a degree in liberal arts did not gain him an advantage for the position of canonry, he already left Cracow without a degree (Goddu, 2010, p.24). On 22 February 1496, he went near his uncle to the bishopric palace in Heilsberg which is now called Lidzbark Warminski. Since the 13th century, the town located in the northeastern Poland has originally belonged to the Teutonic Order, but after the Second treaty in 1466, the town integrated to the Polish province. Copernicus stayed there until he and his brother, Andreas, traveled to Bologna for the winter semester starting on 19 October 1496 (Gassendi & Thill, 2002, p.37).

The main motive for Copernicus to study in Italy was the power of a degree taken from an Italian school (Goddu, 2010, p.24). Additionally, uncle Lucas was taught and graduated from the university in Bologna. Studying law either in France or Italy was a kind of tradition among Germans with money. Apart from those major reasons, there were also some minor impulses such as Copernicus's humanistic interest to Bologna which he gained from the classes of poetry and rhetoric at the University of Cracow, and his wish to be around the contemporary movements in Italy basically pertaining to astronomy and mathematics which also contained the new model of Ptolemy (Goddu, 2010, p.22-23).

Copernicus brothers lived in the house of Dominico Maria da Novara of Ferrara as tenants during their years in Bologna. He was a Doctor of Arts and Doctor of Medicine. He was known by his yearly prognostications which were making predictions about the following year such as the date of the Easter, the weather conditions, the phases of the moon, the times of eclipses, and possible conjunctions of constellations and planets (Gassendi & Thill, 2002, p.39). Both Andreas and Copernicus studied canon law in Bologna, but Andreas started three semesters later than Copernicus. It might be the case that the early career plans of Andreas were different. After all, he might change his mind and decided on studying law instead. Andreas likely had a desire for being a businessman like his father, but could not follow his dream either because of not having enough capital or because he listened to his uncle's advises about being a vacant canonry (Gassendi & Thill, 2002, p.43). Consequently, this delay in Andreas's decision about what his field to study and earn his living would be produced some unpleasant results for his professional life. When Copernicus became an official canon to the chapter of Varmia on 20 October 1497, Andreas had to wait for the same position until 1499 (Gassendi & Thill, 2002, pp.42-43).

Copernicus finished his education in canon law in Bologna on 6 September 1500 (Gassendi & Thill, 2002, p.44). Before the graduation, Copernicus might have a journey to Rome for a few weeks because of his jubilee year. Even though the details of his journey were not documented, he might give lectures on mathematics (Gassendi & Thill, 2002, p.45). Aside from the possibility of experiencing teaching, there is a recorded data about an observation of a lunar eclipse dated by Copernicus as 6 November 1500 which corresponded to his days alleged to spend in Rome (Gassendi & Thill, 2002, p.45).[42] In May 1501, Copernicus and Andreas went back to Poland. After staying there for a few months, they traveled to Frauenburg in the 27th of July in order to ask two-year extension from the chapter of Varmia for completing their education. The chapter gave the permission to Copernicus to study medicine in Padua and Andreas to graduate from the University of Bologna. They planned to go back to Italy for the winter semester of 1501-1502. On 3 August 1501, it is highly probable that Copernicus brothers joined Bernard Sculteti in his trip from Frauenburg to Rome (Gassendi & Thill, 2002, p.46).

The details of Copernicus's studies in Padua were not documented. The only explicit information about his education in medicine was his leaving Padua after two years without a diploma.[43] However, he continued his studies in canon law in the

[42] In *De revolutionibus*, IV, 14, he was comparing this eclipse with a similar one observed by Ptolemy.

[43] For having a diploma in medicine, three years were required (Gassendi & Thill, 2002, p.46).

doctoral degree in Bologna. There is a discussion about the details of the law education of Copernicus. Even though there is no agreement, some scholars argue that Copernicus might be educated in civil law in addition to canon law.[44] Copernicus's later practice as church administrator and his engagement with the struggles in Varmia against Teutonic Knights can be shown as the supporting details for his acquired knowledge in both civil and canon law (Goddu, 2010, p.175). Whereas there is no agreement on the content of the law education that Copernicus took in Bologna, it is documented that he obtained a doctoral degree in canon law (doctor decretorum) from the University of Ferrara in 31 May 1503 (Gassendi & Thill, 2002, p.47). His studies were supervised by Philip Bardella and Antonio Leutus. As a result of being educated in jurisprudence and dialectic, Copernicus's study in law might have an influence to the development of his skills in argumentation, expression and persuasion.[45] The tight relationship between the courses of law and logic in Italian universities might reinforce Copernicus's knowledge in logical techniques that he already familiarized with during his undergraduate education in Cracow. The skills such as application of logic to the legal issues and dialectical topics peculiar to the law such as topics based on etymology, allusion and conjugates would have been acquired by Copernicus during his years in Bologna (Goddu, 2010, p.179, p.182). Although humanistic jurisprudence was more influential in France and Copernicus arrived to Bologna at a time when humanistic critiques of scholastic tradition were not dominant, we may infer that the effects of Italian humanism on Copernicus were still apparent. The most distinct influences can be listed as Copernicus's attempts to compare sources and texts for reconciliation, to learn Greek and to reform astronomy (Goddu, 2010, p.180).

After Copernicus brothers ended their education in Italy with success, moving Frauenburg to accompany other canons was not the first thing to do. They visited their

[44] Rosen, "Copernicus and Italian Science", 127; Biskup, *Regesta*, 39, no.30; 40-41, no.32; 45, no.44; Malagola, "Aufenthalt",21-25.

[45] Malagola, "Aufenthalt", 30-34; Biskup, *Regesta*, 43, no.44; Grendler, *Universities*, 105.

uncle, Bishop Lucas, in the Episcopal Castle in Heilsberg on his request and stayed there for a few years. The years between 1503 and 1510 can be interpreted as a preparation planned by the uncle Lucas for the later clerical duties of Copernicus (Goddu, 2010, p.180). Copernicus joined his uncle in numerous occasions during these years. They were mostly political meetings such as the Land Diet of the Prussian States at Marienburg and at Elbing in January 1504, a meeting held in May 1504 where Royal Prussia and the Polish King Alexander attended, and the coronation of King Sigismund in Cracow on 24 January 1507 (Gassendi & Thill, 2002, pp.51-52). Besides the companionship to his uncle Lucas, Copernicus also practiced Greek to become able to read science books which have not been translated into Latin yet. He did not neglect to improve his scientific knowledge in spite of his activity in the official meetings. While he was still in Padua, his uncle Lucas arranged another financial support for Copernicus as the scholarship of the church of the Holy Cross in Breslau (Wroclaw) on 11 January 1503. He preserved this income until one of his colleague, Dr. Johannes Rudolpus, was offered as the next candidate for the scholastry. Copernicus resigned voluntarily on 4 February 1538 (Gassendi & Thill, 2002, p.69).

Even though Copernicus was never authorized to work as a medical doctor because of not having a degree in medicine, he was seen, informally, as capable of practicing. In that sense, it could be more appropriate to appreciate his services as a medical practitioner rather than a literal physician (Goddu, 2010, p.175, footnote 6). Nevertheless, Copernicus was appointed as a physician on 7 January 1507 while he was in Heilsberg. His responsibilities were covering the health of the bishops of Varmia. Within the same year, Copernicus cured the illness of his uncle who was the current bishop of Varmia and gained him five more years (Gassendi & Thill, 2002, p.65). Copernicus had many books of medicine. While some of them were including basic information in the form of a dictionary or a practical encyclopedia of medicine, the other were more specialized such as a systematic treatise on fevers written by Michele Savonarola and a famous pharmacopoeia of Dioscorides describing almost six hundreds plants and one thousand medication methods (Gassendi & Thill, 2002, pp.64-65). His procedures opposing the usage of force in treatments were mostly embracing the "moderation of the bitterness of drugs" and "soft manner and talks". Copernicus's pacifist philosophy in medication granted him a good record in contrast with some of his colleagues preferring to practice more radical remedies like bloodletting (Gassendi & Thill, 2002, p.71).

3.2.4. Commentariolus

In 1510, Copernicus left Heilsberg and started to construct his own life in Frauenburg without the guard of his uncle.[46] His studies in astronomy began to gather pace about his leaving. By 1509, he was making astronomical observations in Varmia (Gassendi & Thill, 2002, p.62).[47] His first study known as about astronomy, *Commentariolus,*[48] was written between the years of 1508 and 1512.[49] The main assertion of the book was to introduce "a more reasonable arrangement of circles" because the Earth-centered theory failed to explain planetary motions in harmony with the principle of uniformity (Rosen, 1971, pp.57-58). When the concentricity failed, the eccentrics and epicycles were proposed. When they also could not enough to explain the descending motion of the planets, the equant was recommended. None of them could manage to satisfy the

[46] Copernicus might leave Heilsberg either as a result of the change in his decision to be a bishop or to make a more devoted study of the sky. However, there was no document indicating the exact date of his leaving and so, none of these two claims could be analyzed more deeply (Gassendi & Thill, 2002, p.60).

[47] On 2 April 1509, Copernicus observed an eclipse of the moon. The novel computational results of the observation were already noted by Ptolemy (Gassendi & Thill, 2002, p.140).

[48] The original book had no title. *Commentariolus* was the short version of the title invented by Tycho Brahe. The long title in English was "*Nicolaus Copernicus' little treatise on the hypotheses formulated by himself for the heavenly motions*" (Gassendi & Thill, 2002, p.135).

[49] The terminus ante quem for the completed version of *Commentariolus* was constituted by Thilly as 1 May 1514. The date was referring a note taken by a professor in Cracow for the inventory of his library and it contained a copy of a book which was described as *Commentariolus* without any doubt (Gassendi & Thill, 2002, p.140).

requirements of the uniform motion. Therefore, Copernicus challenged the perfectness of the Earth as an immobile center and put it into a more reasonable position as "revolving about the Sun as any other planets" (Rosen, 1971, p.59). The book was explaining the motions in heaven, or more poetically "the entire ballet of the planets", with the help of thirty-four circles which are accordingly seven circles for Mercury, five for Venus, three for the Earth, four for the Moon, five for each of Mars, Jupiter and Saturn (Rosen, 1971, p.90). Copernicus claimed to reduce the number of epicycles in comparison with Ptolemy's model, but Koestler argues its opposite (Koestler, 1959, p.192). Koestler counts the epicycles used in Copernicus's system and finds the number of forty-eight. Koestler also argues that, contrary to popular misconception, Ptolemy's system had only forty epicycles. So, the basic mathematics proves that Copernicus did not decrease but rather increased the number of epicycles. Even though Koestler miscounted the epicycles and Copernicus were right, it does not entail the computational simplicity of his system. As Neugebauer and Gingerich declares, Copernicus's system was complicated as much as Ptolemy's (Neugebauer, 1968, p.97) (Gingerich & Oskin, 1996, p.93).

This new model in *Commentariolus* was largely built on seven postulates (Rosen, 1971, pp58-59). The word "axiom" was used interchangeably with the "postulate". However, it referred to a softer meaning such as "assumptions", "common notions", or "petitiones", rather than its modern meaning as self-evident principles (Goddu, 2010, p.243). The first three postulates claimed the non-uniqueness of the center of the universe and replaced the center of the planetary system which was earlier reserved for the Earth with the Sun. The fourth postulate declared that the distance between the Earth and the Sun was insignificant compared to the distance from the Earth to the stars. The last three postulates were stated to clarify some apparent motions of the firmament, of the Sun and of the planets as retrogressions and stations. While some of these postulates was revised later like the postulate on the uniqueness of the center of the gravity, most of them was preserved like three motions of Earth -daily motion, annual motion and motion in declination-, the center of the universe in the vicinity of the Sun and the retrogression of planets. The study was not widely distributed and so, the names of the people who might read it while Copernicus was still alive were open to discussion, except Bernard Wapowski (Gassendi & Thill, 2002, p.141).

During and after writing *Commentariolus,* Copernicus was professionally engaging many other occupations, too. Between the years of 1516 and 1519, he was the administrator of the property held in Common in Varmia. He was directing the taxes, the procedures about the changes of the ownership of lands, and the other charity works like helping peasants. In 1516, Copernicus answered the 5th Council held at the Lateran Palace in Rome, which was responsible from the preparation of the new calendar between 1512 and 1517. The desire of the papacy to reform the calendar for calculating the length of the year more accurately was directed the council to astronomers and one of them was Copernicus.[50] In 1516, he wrote about his studies focusing on the motion of the Sun and the Moon to the Bishop Paul of Middelburg who was a professor of mathematics at Padua and a participant of the Council of Lateran (Gassendi & Thill, 2002, p.164). Copernicus might not satisfied about the studies carried out at the Council, because he thought that the rate of the precession of the equinoxes varied and so, the length of the year could not be constant. However, it is highly probable that a detailed report was sent to Bishop Paul by Copernicus to show his dedication to Holy Father and to please the Pope’s desire for the reformation (Gassendi & Thill, 2002, pp.164-165). In the meanwhile, Copernicus was dealing with the recoveries of losses and accusations of murders and robberies committed by the Teutonic Knights (Gassendi & Thill, 2002, pp.92-93). For two years starting from 1528, he also participated actively to the commissions about the current value of money in comparison with those in old days (Gassendi & Thill, 2002, p.86). He also wrote very shortly about the price of the bread

[50] The preparation of Julian calendar was finished in 1582. The length of the year was not constant and the elders believed that it was the case because of the variation of the rate of precession of the equinoxes. Eventually, the error was found and the reason of this instability was corrected. It was because of the gravitational force performed by other planets. This thesis was also presented in *De revolutionibus*, I, 9.

around these years, but the exact date is not known (Gassendi & Thill, 2002, p.87). In 1531, Copernicus and Tiedemann Giese became the guardians of the chapter's table and performed accounting. Copernicus was also keen on maps and possibly drawing maps between 1510 and 1529. A map drawn with Alexander Sculteti, a fellow canon helping Copernicus in his observations with Giese, was known dated in 1531 (Gassendi & Thill, 2002, p.196).

Besides all of these official assignments, Copernicus performed actions of civil disobedience, too. On August 1517, Copernicus wrote a brief treatise in Latin on the money regarding debasement of currency. The Teutonic Knights were decreasing the value of the money by increasing the amount of producing coins. Since the mints in West Prussia were run by the Teutonic Order, they decided to diminish the cost of coinage by using poorer alloy. Copernicus was criticizing this policy because he believed that the debasement of coinage was symbolizing the decline of the fatherland (Gassendi & Thill, 2002, p.84). The other civil action of Copernicus was resisting against leaving the Castle of Allenstein (Olsztyn) sieged by Teutonic Knights. The castle was surrounded for 12 days starting from the tenth mount of the war which broke out on the 1st of January in 1520 and continued until April 1521. This stand-alone passive defense of the castle was the beginning of the confrontations of Copernicus with the Grand Master of Teutonic Knights, Albrecht von Hohenzollern, who besieged Allenstein.[51]

[51] Albrecht became the first monarch of the Duchy of Prussia which was established during the Protestant Reformation in 1525, succeeding the monastic state run by the Teutonic Order. While Albrecht was the Duke of Prussia, he asked a favor from Copernicus in 1541. The illness of Albrecht's counselor, Georg von Kunheim, was treated by Copernicus in Koenigsberg in less than three mounts (Gassendi & Thill, 2002, p.70). This was the second meeting of Copernicus and Albrecht after the one in the Castle of Allenstein.

3.2.5. De revolutionibus

Copernicus started writing his magnum opus, *De revolutionibus*, circa 1525 (Goddu, 2010, p.xxiii). The edition and printing processes of the book could not be finished utterly even in his last days in May 1543. When *De revolutionibus* is compared to *Commentariolus*, the former presents more accurate information about the heavens. For instance, the calculations about the time required for the revolution of Mars and Venus were fitting more to the reality, and the variations in the positions of the apsides, which are the two farthest points in an eccentric orbit, was presented for the first time (Gassendi & Thill, 2002, pp.161-162). *De revolutionibus* was also critical about some findings of *Commentariolus* like the centralization of the gravity. In the second postulate of *Commentariolus,* the center of the Earth was regarded as not only the center of the universe, but also the center of the gravity (Rosen, 1971, p.58). However, in *De revolutionibus*, gravity was not declared anymore as centered by the Earth only. The possibility of the gravitational drive to be possessed by the Sun, the Moon and other planets, too, was admitted (Copernicus, 1992, I, 9). According to his new thesis, the universe had multiple centers of gravity and this view was challenging Aristotelian physics, which defended a geocentric and geostatic universe. It was also conflicting with all other homocentric (concentric) models, where whole heavenly bodies revolved around an identical center, such as the models of Arabs, Averroists influenced by Ibn Rushd and Alpetragius (al-Bitruji) (Gassendi & Thill, 2002, p.152, p.202) (Goddu, 2010, p.118). In Copernicus's words, "this impulse is present, we may suppose, also in the sun, the moon and other brilliant planets" (Copernicus, 1992, I, 9). According to him, this impulse was also the reason of their spherical shape, their form of a globe. The multiplicity of the center was assumed the first step on the track of formulating the law of universal gravitation by Newton. This thesis, in a premature form, was expressed by Copernicus in *De Revolutionibus,* and in this respect, he can be entitled as the "Newton of the Renaissance" (Gassendi & Thill, 2002, p.152).

Copernicus gained fame in his old ages, more precisely, while he was sixty-five. In 1538, Bishop Dantiscus and Canon Geise encouraged Copernicus to publish his revolutionary manuscript which had been written long since. This year was the turning point of his life (Gassendi & Thill, 2002, p.173). A year after, he met with a professor from Wittenberg named Georg Joachim Rheticus and his studies as a pupil contributed greatly to the presentation of Copernicus's ideas. Rheticus (1514-1574) was a protestant professor giving lectures on mathematics, arithmetics, geometry and, occasionally, astronomy. He left the University of Wittenberg on 18 October 1538 to visit preeminent astronomers in the southern Germany. Around the middle of the year 1539, he came to Frauenburg to meet Copernicus via the advice of Schöner who was a professor of Astrology (Mathesis) in Nuremburg (Gassendi & Thill, 2002, p.176). The intention of Rheticus's visit was learning the new tenets of astronomy from directly an expert. In those years, Copernicus had a reputation of developing a new heliocentric system. So, Rheticus was "impatient" to hear the defense of the theory from its originator, Copernicus, and to check whether "the rumors that are circulating" were true (Gassendi & Thill, 2002, p.176).

Until 1541, Rheticus stayed with Copernicus and read and worked on his manuscript subtly. It is known that Rheticus's opinion was mostly corresponding to the commonsense and common interpretation of the God's words, and so, he was not fully satisfied by heliocentric theories in general (Gassendi & Thill, 2002, p.198-201). He was also critical about, but not against, Copernicus's ideas but still he asked Rheticus to carry out a study on the manuscript. This favor requested from him might be seen as a proof that Copernicus had serious concerns about being behind the schedule for preparing the manuscript for printing. Since it was possible for him to need time to complete and revise his manuscript, and so, to desire postponing the publishing date of his book, Copernicus might burden such a challenging and time-consuming work to Rheticus's shoulders (Gassendi & Thill, 2002, p.185). As he claimed, Copernicus might avoid disclosing his revolutionary thoughts not to enter a destructive discussion, and so, he might delay so much the publication of *De revolutionibus* (Gassendi & Thill, 2002, p.199). However, there were also many cases that can be interpreted as strong counter-proofs to Rheticus's assertion pertaining to Copernicus's fear about the days following the publication of the book. For instance, the most controversial parts of Copernicus's thesis were already presented in *Commentariolus* such as three motions of the Earth. Additionally, his friends, colleagues and bishops that he was in contact were not outlandish to the conversations including his radical theories. Even, one of these bishops, Dantiscus, who encouraged Copernicus at first hand, supported him by writing a poem for *De revolutionibus.* Also, Geise, one of Copernicus's backing friends, published a booklet about his system but unfortunately it lost (Gassendi & Thill, 2002, p.199). Therefore, it is not plausible to confirm Rheticus's claim about Copernicus and his diverted decisions by fear. These allegations can be construed as suppositions of a pupil based on his cloudy relationship with his tutor (Gassendi & Thill, 2002, p.198, p.227).

Rheticus and his mentor, Copernicus, were diverging in their personality and interests unlike their agreeable opinions on scientific issues. For instance, on the one hand, Copernicus was shy, supporter of justice and inequality, did not value money greatly, and devoted to astronomy. On the other hand, Rheticus was rather extravert, eager to earn more money and valued judiciary astrology deeply (Gassendi & Thill, 2002, p.198, p.227). In addition, they have a forty-year age gap, regional differences and dissimilar social origins. Rheticus was christened Iserin, but they were forced to change their name after his father had sentenced to death because of sorcery (Gingerich, 1992, p.69). Nevertheless, they were sharing the same taste in their interest to mathematics and medicine,[52] incuriosity to theological questions, enthusiasm to learn new languages and

[52] As oppose to Copernicus's passive philosophy in medicine, Rheticus adopted more extreme Paracelsianism which was the doctrine of Paracelsus (1493-1541) (Gingerich, 1992, p.69). This medical movement was regarded as radical because of its criticism to the scholastic medicine which referred to the ancient texts and was not convinced of exercising natural experiments. In that sense, Rheticus and Copernicus were also dissimilar in the philosophy of their medical practices.

more essentially, they both were not holding unshakable prejudices against the heliocentricism (Gassendi & Thill, 2002, pp.184-188).

After a challenging study on *De revolutionibus*, Rheticus was able to write a promotional work to guarantee the success of the book (Gassendi & Thill, 2002, p.185). *Narratio Prima* was an abbreviation of Copernicus's *De revolutionibus* consisting of thirty-six leaves and was written in ten weeks in 1539 (Rosen, 1971, p.109). Since the book was written on the purpose of taking the pulse of men of science, the part concerning the motion of the Earth was presented in the final section. In 1540, *Narratio Prima* was printed under the supervision of one of Rheticus's pupils, Heinrich Zell, in Danzig. The study was received favorably by the scientific community and the second edition was printed in Basel one year later (Gassendi & Thill, 2002, p.191).[53]

In May 1542, first two books of six-volume *De revolutionibus* were published at Petreius bookshop at Nuremburg and the publication process was supervised by Rheticus and Andreas Osiander (1498-1552). The book was dedicated to Paul III, the Pope.[54] The book was prepared for the publication mostly by Osiander who was a Lutheran interested in theology as an amateur. He was editing books for Petreius who

[53] The reception of *De revolutionibus* was partially guaranteed by the success of *Narratio Prima*, but still Copernicus's ideas faced some highly critical evaluations after the publication of *De revolutionibu*s. For instance, Jean Bodin (1530-1596) accused Copernicus of having two absurdities in his work, which were the centricity of the Sun and the three "natural" motions of the Earth rather than one. Giulio Cesare LaGalla (1571-1624) declared that Copernicus's ideas were contradicting to the "common sense of all men, educated and uneducated" (Gassendi, pp.278-283). A prominent professor at Wittenberg, Phillip Melanchton (1497-1560), referred to Copernicus in a letter as someone having "impudent" opinions and "ought to be repressed by wise governments". In addition, Melanchton, in his book, *Initia doctrinae physicae*, published in 1549, claimed that such a conclusion of Copernicus about the Earth in motion was an "old joke" and could only be written "from the love of novelty" (Gassendi & Thill, 2002, p.217). Some of the critics of Copernicus were not public, but more like a personal note written in the margins of the book-copies. For instance, Jesuit astronomer Christopher Clavius (1538-1612) commented on an erroneous trigonometric theorem in *De revolutionibus* as "Here Copernicus is dreaming!" Some of the anonymous annotators were repeating the comment of the Sicilian astronomer Frencesco Maurolycus (1494-1575) on Copernicus, which was that he "deserved whips and lashes" for his unconventional cosmology (Gingerich, pp.73-74).

[54] Giese was a Lutheran and the dedication of *De revolutionibus* to the Pope did not pleased him. In one of his letters to Rheticus in 1543, Giese also complained about the insufficient appreciations of Copernicus to Rheticus for the preparation of the book (Gassendi & Thill, 2002, pp.197-198)

was the authority for publishing scientific texts in the 1540s and had the facilities for press and the network for distribution (Gingerich, 1992, p.70). During the preparations of *De revolutionibus,* Osiander decided to add a preface. He required this addition because he had some worries about negative feedbacks of the readers "shocked" by the thesis defended against the immobility of the Earth (Gassendi & Thill, 2002, p.213). During 1541, there were some letters send by Osiander to Rheticus and Copernicus with the intention of indicating his concerns (Gassendi & Thill, 2002, p.215). However, nothing was noted about the letters which can be the indicative of Copernicus's consent for making some arrangements in the general structure of the manuscript to relieve Osiander. Nevertheless, he sketched a preface for the readers. He stated that Copernicus's writings on the motion of the Earth and the centricity of the Sun were "not put forward to convince anyone that they are true, but merely to provide a reliable basis for computation" (Copernicus, 1992, xx). This preface was not welcomed by Rheticus and Giese, and the Petrius bookshop was blamed for this unfortunate statement (Gassendi & Thill, 2002, p.214) They made a legal complaint pertaining to Osiander to the city council of Nuremburg but he was not punished.

When Rheticus commissioned Osiander to do the proofreading and left the Nuremburg, the front matter of the book was not completed yet. According to Gingerich, it is very likely that the book was prepared for the publication with another foreword such as a "laudatory poem" which was very common in scholarly books of the 16th century (Gingerich, 1992, p.72). In one of the copies of the *De revolutionibus* signed by his single pupil, Rheticus, a long poem written in Greek in 1543 by Joachim Camerarius, who was a leading professor in Leipzig, found on the flyleaf. In a poetic dialogue, a stranger asks "What is this book?" and the philosopher replies "A new one, with all kinds of good things in it". Then, the stranger becomes pleased and says "O Zeus! How great a wonder do I see! The earth whirls everywhere in aetheral space". But, the philosopher warns "Do not merely wonder, nor condemn good thing as the ignorant do before they understand, but examine and ponder all these things". A Latin poem whose origins were based on this Greek poem was also written by Kepler to his own copy of *De revolutionibus.* The poem was signed as "I K". These initials can be interpreted both for "Iohannes Kepler" and the Greek version of Camerarius's name with capitals, "Ioachim Camerarius" (Gingerich, 1992, p.73).[55] According to Gingerich, the fact that Osiander's preface was crossed off with a red crayon in Rheticus's copy might be, in addition to the dissatisfaction about Osiander's words, a result of the removal of Camerarius's poem.

There are other passages deleted from the autograph of *De revolutionibus*, but in this time with the consent of Copernicus, and not printed in the first editions. One of them is known as the Letter of Lysis which is regarded as the indication of Pythagorean roots of Copernicus's heliocentric theory (Copernicus, 1992, pp.25-26).

> The motion of the sun and the moon can be demonstrated, I admit, also with an earth that is stationary… Philolaus believed in the earth's motion for these and similar reasons. This is plausible because Aristarchus of Samos too held the same view according to some people…. But only a keen mind and persevering study could understand these subjects [about the theory of heavenly bodies]. They were therefore unfamiliar to most philosophers at that time… Even if these were known to Philolaus or any Pythagorean, they nevertheless were probably not transmitted to posterity. For it was the Pythagoreans' practice not to commit the secrets of philosophy to writing nor divulge them to everybody, but to entrust them only to faithful friends and kinsmen, and pass them on from hand to hand (Copernicus, 1992, p.25).

Since keeping these theories in secret was required by Pythagoreans, this letter was written to Hipparchus, who taught philosophy publicly, to remind his oath and to show the consequences of its violation. According to the custom, Pythagoras's lofty precepts were assumed treasures of philosophy and so, selling them for a price was forbidden. Lysis was using an analogy in his letter and compared Hipparchus's act with "pouring pure fresh water into a deep well full of muck" (Copernicus, 1992, p.26). This analogy was indicating that the gentleness of the souls and the reasonableness of those who were taught by Hipparchus with an inappropriate procedure could be damaged.

[55] This detail was recognized by Jerzy Dobrzycki.

This passage was partially transmitted to the preface as follows: "I found in Cicero that Hicetas supposed the earth to move. Later I also discovered in Plutarch that certain others were of this opinion" (Copernicus, 1992, preface, p.4). In the quotation of Plutarch, the name of the Philolaus the Pythagorean was retained, but Aristarchus was omitted, most probably because of the carelessness (Gingerich, 1992, p.68). Still, his ideas were familiar to Copernicus. Although the famous book of Aristarchus, *Sand-Reckoner*, was published after a year of Copernicus's death, he was quite informed about Aristarchus's ideas by the means of Plutarch. A few pages before the passage of Plutarch quoted by Copernicus in the preface of the *De revolutionibus*, these words were written: "Ought the Earth …be understood to have been devised not as confined and at rest, but as turning and whirling about in the way set forth later by Aristarchus and Seleucus, by the former only as a hypothesis, but by Seleucus beyond that as a statement of fact?" (Gingerich, 1992, p.68) This work of Plutarch, or more properly of Aetius whose works were alleged to be written by Plutarch, was translated by Giorgia Valla (1447-1500) from Greek to Latin and published posthumously in 1501. There are also evidences for Copernicus's consultation to this book in *Commentariolus* and to the other translations of Valla for the definition of some astronomical facts and the numerical values in *De revolutionibus* (Goddu, 2010, p.229).[56] The translation of Valla was a collection of the ancient views, where pseudo-Plutarch's *De placitis philosophorum* was also included. According to Rosen, the reason of the removal of Aristarchus's name and ideas about geokineticism is the mistranslation of Valla (Copernicus, 1992, commentary, pp.360-361). Pseudo-plutarch originally stated in Greek that "According to Aristarchus, the Sun and the fixed stars are stationary, while the Earth revolves around the ecliptic". But in Valla's translation, it distorted and converted into that "Aristarchus locates the Sun beyond the fixed stars". Rosen's interpretation strengthens the claim that Copernicus did not read the work in Greek, but rather in its Latin translation. Since the Latin copy was

[56] For the influence of the Valla's translations on *De revolutionibus,* Goddu refers to Edward Rosen's commentary on Copernicus's *On the Revolutions.*

not within reach of Copernicus until 1516,[57] the influence of Aristarchus's heliocentric ideas on Copernicus could only be possible in the form of the details for a study which had already been defended independently before 1514 (Gingerich, 1992, p.68).

If none of these ideas had a major influence on Copernicus, what could lead him to construct a heliocentric model of the universe? The most influential resources for the arguments in Copernicus's *De revolutionibus* were regarded as the publications which were newly written around the year when Copernicus arrived in Bologna, which was the late 1495 and early 1496 (Barker, Dear, Christianson, & Westman, 2014, p.204). The most significant ones were as follows: Albert of Brudzewo's *Commentary on Peurbach's New Theoricae*, Regiomontanus's (Johannes Müller von Königsberg) *Epitome of the Almagest*, Alessandro Achilini's *De orbibus*, Giovanni Pico della Mirandola's *Disputationes*. Brudzewo was critical about the equant as a real existence, Regiomontanus was the writer of a critical commentary on Ptolemy and this book was widely used due to the absence of *Almagest*'s printed edition, Pico was an astrological skeptic, and Achilini was an Averroist attacking on Ptolemaic astronomy. About the origins of Copernicus's heliocentric theory, there were two main claims defended by Bernard Goldstein (2002) and Noel Swerdlow (1973). On the one hand, according to Goldstein, Copernicus adopted heliocentrism because only then, the planets could be ordered considering the principle of that the more distant the planet is from the center of the universe, the less velocity it will have for rotating (Goldstein, 2002). The view of Goldstein was criticized by Robert Westman because the adoption of the principle about the inverse proportionality of the distance and the velocity by Copernicus was for demonstrating a hypothesis against the attacks of skeptics like Pico (Westman, 2011, p.105). On the other hand, according to Swerdlow, Copernicus was firstly favoring an intermediate solution similar to Tycho's geo-heliocentric model with an inspiration of

[57] A connection between a copy of the Latin edition of pseudo-Plutarch and the cathedral library where Copernicus was employed as a canon was discovered at a later date. Since this copy in the library was printed in 1516, it was believed that he could only then have access to the favorable views of Aristarchus about the heliocentric cosmos (Gingerich, 1992, p.68).

Regiomontanus, but when he realized that this solution was threatening the reality of celestial orbs, he turned into heliocentrism (Swerdlow, 1973). However, Swerdlow's reasoning was problematic in many respects. The most major problem was about timing. Even though Swerdlow argued that Copernicus could adopt Tycho's solution at any time up to 1532, it is mostly agreed that *Commentariolus* was written no later than 1510 (Barker et al., 2014, p.206). Barker argues that the most plausible proposal about the origins of Copernicus's heliocentric model was made neither by Goldstein nor by Swerdlow. Westman achieved this without giving any chance to the questions like "why Copernicus offered such a solution at that historical moment?" (Barker et al., 2014, p.207). According to Westman, Copernicus was well informed about the attacks on Ptolemaic science of the stars, which had two aspects as the astronomy and the astrology. The attacks on the latter were mostly performed by the skeptics such as Pico, and the former was by the Averroists such as Achillini. According to Barker, what makes Westman's suggestion distinguished from the others is firstly, staying away from the anachronistic categories, and secondly, approaching to the notion of "historical causation" as something not ending within the limits of science, but rather extending all through the culture (Barker et al., 2014, p.208). It is true that the justification of the Ptolemaic science of stars by Copernicus was rooted in astronomy. However, the discovery of a novel arrangement about the motion of heavenly bodies was motivated by his interest in astrology as well as the matters in astronomy.

By starting such a long-continued polemic, the first edition of *De revolutionibus* was printed approximately five-hundred copies in March 1543.[58] A year before, in June 1542, Copernicus's mathematical treatise, *De triangulorum,* was published by Iohannes Lufft in Wittenberg. The complete name of the book was *De Lateribus et Angulis Triangolorum* and the subject was triangles which had a place in understanding the ratio of movements and were simplifying to work on the illustrations of Ptolemy (Gassendi &

[58] The 2nd edition printed with *Narratio Prima* in 1556, the 3rd edition with some additions in Amsterdam in 1617, the 4th edition translated to Polish and printed in Warsow in 1854, the 5th edition in Torun in 1873, the 6th edition in Munich in 1949 and in 1978 the book was translated to English by Edward Rosen.

Thill, 2002, p.192). The treatise was written with Rheticus and dedicated by him to Georg Hartmann. *De triangulorum* was later inserted in *De revolutionibus.*[59] Copernicus could not spare his time to overview its printed copy coming a few hours earlier from his death (Gassendi & Thill, 2002, p.225). In the beginning of 1543, he had already semi-paralyzed because of a problem occurred in the flux of his blood and this illness which started in 1542 proceeded with memory loss. On 24 May 1543, he passed away by leaving behind a rumor about a love affair with a woman named Anna[60] and the adoption of three orphans of Reinhold Feldstadt.[61]

3.3. Copernican Questions in the Reconstruction of the Heliocentric Programme

It is highly probable that the first step of Copernicus's inquiry for constructing his new cosmology was questioning the lawfulness of Ptolemy's equant. It was a geometrical device used for explaining the variations in the speed of planets. The main motivation of Ptolemy to invent this tool was offering a solution which was consistent with the ancient Greek tradition. The ancients believed that universe was geocentric and geostatic, which means that the Earth rested at the center of the universe. Their belief was depending on Aristotle's natural philosophy, and according to this doctrine, the earthly matter was naturally tended to fall towards to the center because of its weight. So, the Earth, as a body whose desire was to reach its natural place, was being pulled towards the center. When the Earth reached to the center and fulfilled its natural desire, it remained

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[59] Rheticus endeavored to extend the work but the table of tangents and secants could be completed hardly in 1613 by Bartholomeo Pitiscus (Gassendi & Thill, 2002, pp.193-194).

[60] Anna Schilling was a housekeeper who loved by another bishop, most likely Dantiscus, but she chose Copernicus to stay near around 1539. This affair can be a gossip to defame Copernicus and to dishonor his friends Niederhoff, Sculteti and Geise. Copernicus with his friends, Niederhoff and Sculteti, wanted to be excommunicated from canonry after a few mounts and Geise managed to rescue the status of Copernicus and Niederhoff, but not of Sculteti (Gassendi & Thill, 2002, pp.232-234).

[61] Reinhold Feldstadt was married with the daughter of Copernicus's uncle, Tileman von Allen. After Reinhold's death in 1529, Copernicus became the legal guardians of the orphans (Gassendi & Thill, 2002, p.232).

motionless (Finocchiaro, 2010, pp.7-8). This simple line of thought was the reason of the ancients to believe that Earth was at the center, which entails the geocentric model, and had no motion, which entails the geostatic model. Not to get into conflict with such a rooted tradition, Ptolemy tried to explain the violated motions of the planets by some mathematical re-arrangements, and reserved the basics of the ancient model. Such mathematical adjustments were acceptable by the Greek tradition, because it was believed that these astronomical models were not realistic visualizations of heavens, but rather some formulas or number series to predict the location of heavenly bodies at a given time. They were mathematical maneuvers or tricks for deceiving the universe and solving a part of its riddle whose actual solution was unreachable by us (Bauer, 2015, p.55). Greeks were calling these attempts as “saving the phenomena” which meant producing some geometrical models to be matched with the observed phenomena. Ptolemy’s equant model was one of them and it was dividing the reference point for the uniform and circular motion of the planets into two as the equant and the Earth. In his model, while the Earth as the center of the universe was responsible for keeping a uniform distance with the planets surrounding it, the equant was assisting the centricity of the Earth by empowering it to have a sight to observe planets at a uniform speed. So, a complete explanation of the uniform motion could merely be accomplished with the help of a mathematical point which was indeed occupied by nothing. Therefore, his maneuver was a*d hoc*, which meant that the equant was a solution designed for a specific problem, which was the retrogression of planets. It could neither be generalized nor remain permanently consistent with other parts of the Ptolemaic model.

Ptolemy solved the discrepancy between what was predicted by the theory and what was observed in the heavens by reproducing the observed motion of the planets in a mathematical model. However, according to Copernicus, this solution was “neither sufficiently absolute nor sufficiently pleasing to the mind” (Rosen, 1971, p.57). Even though Ptolemy’s device enabled him to stay consistent with the numerical data, Copernicus believed that Ptolemy violated the axiom of uniformity (Rosen, 1971, p.29).

Actually, Ptolemy's equant could not even manage to stay consistent with the numerical data for a long time. His system could never work so sensitively, but with the passage of time, the deviations of the Ptolemaic model became more apparent (Kuhn, 1995, p.140). Kuhn makes an analogy to explain the situation clearly. He compares the motion of the planets around the deferents and epicycles to the hands of a clock, and says: "If a clock loses, say, 1 second per decade, its error may not be apparent at the end of a year or the end of ten. But the error can scarcely be evaded after a millenium, when it will have increased to almost 2 minutes." (Kuhn, 1995, p.140) When we consider the time span between Ptolemy and Copernicus, which was over than thirteen centuries, it is unavoidable to conclude that the astronomical data collected by Copernicus and his contemporaries was much more precise than Ptolemy's. At least, it can be defended that they had more sensitive checking-systems which could be applied to the raw data and decrease the deviations. Copernicus's skepticism about Ptolemy's modification and the attempt of finding an alternative to it in Aristotelian celestial physics can be seen in the following inquiry. "Whether there could perhaps be found a more reasonable arrangement of circles, from which every apparent inequality would be derived and in which everything would move uniformly about its proper center, as the rule of absolute motion requires" (Rosen, 1971, p.57). According to Copernicus, such an "arrangement" could only be established when a single and unique center was defined for the motion of the planets. In Aristotelian physics, the universe was believed to divide into two as the earthly and the heavenly regions. For instance; while the bodies which belonged to the terrestrial region moved naturally with straight motion and experienced qualitative change, the natural motion of the bodies belonging to the celestial region was circular and they subjected to no change (Finocchiaro, 2010, p.10). Within the earth-heaven dichotomy, the superiority was given to the celestial region and so, the perfect motion, which was uniform and circular, was attributed to the celestial bodies. Since the circularity resembled the smoothness and being at rest, the perfect bodies of heaven were believed to move circularly around the same center, which was Earth.

By staying loyal to his Aristotelian roots, Copernicus suspected the correctness of Ptolemy's mathematical representation.[62] Ptolemy preferred to be agreeable with the observations, rather than having recourse to the postulates of the Aristotelian physics. He adhered to the predictive results of his mechanism more than its physical reality (Gingerich, 1993, p.25). According to Copernicus, this choice caused Ptolemy to fail to give a genuine explanation for planetary motions. To provide a justifiable ground for his belief, Copernicus began to question Ptolemy's arguments. It is known that he mostly benefited from the observations of the Babylonian astronomers, who were reputed to make systematic observations and have detailed records about the motions of heavenly bodies (Gingerich, 1993, pp.20-21). It is also known that a remarkable amount of the planetary observations which were cited in Copernicus's manuscripts originally belonged to Ptolemy's *Almagest* and *Epitome* (Neugebauer & Swerdlow, 1984, p.357). So, it was not very likely to think that Copernicus suspected from the sources of the observational data. Or at least, we can assume that even he had minor suspicions, he was not able to re-perform all of these observations and check the results.[63] Therefore, he counted upon the previously collected data by Ptolemy. The only way for him to hunt after Ptolemy's equant was questioning his version to apply the observational data to the representation of the universe. Copernicus was aware of a very basic physical rule about motion, which was "every observed change of place is caused by a motion of either the observed object or the observer" (Copernicus, 1992, I, 5). This rule was logically entailing two equally defendable claims: "The images of heaven, as observed from the

[62] Goddu claims, by referring to Mieczyslaw Markowski's *Astronomie als Leitwissenschaft*, that Copernicus met Aristotelian works during his university years in Cracow. The curriculum of the university encouraged Copernicus to embrace the transition of old astronomy to its modern interpretation by preserving his ties with Aristotelian tradition (Goddu, 2010, p.99). A similar claim about Copernicus's Aristotelian ideas on physics is emphasized by Koestler. He calls Copernicus as "the last of the Aristotelians" (Koestler, 1959, p.197).

[63] There are suspicions about how Ptolemy found the required numerical parameters for constructing an epicyclic model for the planets. He might have taken a small list of well-chosen observations and accorded his parameters to them. Or, he might have used a long list of observations and pinpointed an average by considering the best frequency for the solution. This mysteriousness about Ptolemy's choice for the parameters of his tables and some problems with his data were realized in some degree but generally ignored (Gingerich, 1993, pp.16-18).

Earth, *do change* because of the motion of the Sun, the moon, and the planets" and "The heaven with all of these bodies *seems to change* because of the motion of the observer, which is the Earth". This sort of a logical reasoning led Copernicus to reconsider the foundations of Ptolemy's arguments which kept him in the safe area of geocentricism.

Copernicus also questioned why Ptolemy was afraid of the idea of a mobile Earth, but not the idea of a universe in motion (Copernicus, 1992, I, 8). Being disrupted and disintegrated by the influence of the rotation was also a possibility for the universe as a whole. Even the consequences would be harsher than the hypothetical case of a mobile Earth. Since the universe is bigger and so, its motion is more rapid, it would be logical to think that the rotating one was not the universe, but the Earth. The same question can be expressed differently. Here is another formulation: "Which is it more likely-- that the earth, like a grain of sand at the center of a mighty globe, should turn round once in twenty-four hours, or that the whole of that vast globe should complete a rotation in the opposite direction in the same time?" (Ball, 2009, p.18) According to Copernicus, believing that universe, as an enormous magnitude, was rotating in twenty-four hours was more astonishing even than believing in the rotation of its part, which was the Earth (Copernicus, 1992, I, 6). To support his idea, he had recourse to the physics, again. It was commending a similar reasoning: "motion should not be attributed to the enclosing, but to the enclosed" (Copernicus, 1992, I, 5). Since the heavens were considered as the framework of space and the Earth as a thing locating in space, it would not be wise to identify the Earth as resting. As a result of the agreement on the claim that the heavens remained stationary because it was the enclosing, there was nothing left to argue but that the Earth was in motion. The logical possibility about the source of the motion transformed into a necessity bounded by physical laws: "the appearance is in the heavens and the reality in the Earth" (Copernicus, 1992, I, 8). The mobility of the Earth was producing the impression that the whole universe was in motion. Indeed, the mobility of the universe was just an appearance. This frame of reference was also supported by the conviction that the nobility and the divinity were suiting to the immobility more than the change (Copernicus, 1992, I, 8). In this context, since the heavens were assumed more divine, the Earth had to move.

Copernicus opened a related but small discussion here about the possibility of an infinite universe.[64] He argued "why do we still hesitate to grant it the motion appropriate by nature to its form rather than attribute a movement to the entire universe, whose limits unknown and unknowable?" (Copernicus, 1992, I, 8) To speculate on infinity, he took his cue from optics and gave an example about the limited visibility of heavenly objects. He argued that the sphere of the fixed stars were exempted from any image of change thanks to their enormous height (Copernicus, 1992, I, 10) Since the fixed stars were very far away from the Earth, even its motion cause some false impressions on them, this phenomena would not be observed.[65] Copernicus offered the "twinkling" as a proof for that there were things like stars unlike the planets and these stars were very distant to us. Their existence was supporting the idea of an almost infinite distance between what was moving (the most distant planet Saturn) and what was not moving (the sphere of fixed star) (Copernicus, 1992, I, 10).[66] In celestial physics, the velocity of the motion was proportioned with the circumference of the bodies. There was a direct relation between the vastness of a body and its speed to complete its revolution. He believed that the heavens had to grow into infinity, because it had the highest speed for completing the circadian circuit (Copernicus, 1992, I, 8). Even though such reasoning was in favor of the possibility of an infinite universe, he left the question open to be answered later by the natural philosophers. However, one of the results of this discussion

[64] This discussion about the expansion of the universe towards the infinity caused Copernicus to have a bad fame almost a hundred years later. He was labeled as the "pretender of the seat next to Lucifer's throne" by Reverend John Donne. Since the thickness of the firmament was separating the realms of the astronomy and the theology, Copernicus's extended universe was believed to threaten it and end the intimacy between man and God (Koestler, 1959, p.218).

[65] This was also the reason of why Copernicus was never able to observe an annual parallax with the unaided eye (Gingerich, 1992, p.67).

[66] Copernicus reserved the belief that the stars were fixed to the firmament, or the eight sphere, but they seemed to disappear at nights and appear again on mornings because of the rotation of the Earth.

which he wanted to take advantage was the immobility of the heavens. Since “the infinite could not be traversed or moved in any way”, the heavens, which had a huge possibility of being infinite, had to remain fixed (Copernicus, 1992, I, 8).

After the motion was attributed to the Earth, Copernicus analyzed the possible implications of his geokinetic cosmos. He questioned whether this thesis could strengthen his hand to give genuine explanations for the variations of planetary motions. His basic motive was avoiding to generate anything redundant or impractical, and preferring to enrich a single thing with many effects (Copernicus, 1992, I, 10). His inclination in explaining the universe with a simple but fruitful standpoint directed his inquiry to this question: “to what extent the motions and the appearances of the other planets and spheres can be saved if they are correlated with the Earth’s motions?” (Copernicus, 1992, preface, p.5) To answer it, he tried to figure out a pattern of reasoning in which the motion of Venus and Mercury can be explained without violating the arrangement of the planets in accordance with their relative swiftness and slowness (Copernicus, 1992, I, 10). Before the details of Copernicus’s solution for this anomaly, giving the traditional background for the motion of the planets could be useful. Ancients believed that the universe was finite, bounded by the stellar sphere, also known as the sphere of the fixed stars. But under this outer limit, there were eleven more spheres and all of them were nested like the layers of an onion (Finocchiaro, 2010, pp.6-7). Since the heavenly bodies were carried on these spheres, they were also the route of these bodies to perform their natural motion. The four of these spheres, which were earth, water, air and fire, belonged to the earthly region. The other eight belonged to the heavenly region and were carrying the Sun, the Moon, five planets, and finally the fixed stars. All of the heavenly spheres, except the stellar sphere, were moving equally fast, but differing in the duration of their revolution. Because of this ingrained composition of the universe, the objects farther away seemed to travel more slowly (Copernicus, 1992, I, 10). However, this claim was not enough for explaining the alterations in the annual revolution of two inner planets, which were Venus and Mercury.[67] For the solution of the problem, Copernicus had two alternatives: either rejecting the centricity of the Earth for the revolution of the planets, or disregarding any principle of arrangement and attributing some arbitrary places to the planets. By referring to Martianus Capella's theory about sun-centered revolution of Venus and Mercury, Copernicus chose the first possibility and identified a hierarchy between the spheres with respect to their size and speed (Copernicus, 1992, I, 10). The immovable sphere of the fixed stars was assumed the highest authority because of its enormous size and unchanging location, and then, the planets were ordered with reference to it. Saturn was assumed to be superior due to being the closest planet to the fixed stars. Similarly, the largest path was attributed to the Saturn as thirty years and the time required for an annual revolution was supposed to decline when the planets came closer to the center. For instance, the most inferior planet, Mercury, was declared as completing a rotation every three months (Rosen, 1971, pp.59-60).

It was not possible for the Earth to be treated as the center of all the revolutions any longer (Copernicus, 1992, I, 9). Copernicus had to find a new center. He could adopt an intermediate arrangement as Tycho's geo-heliocentric system in which while the Sun and the moon were rotating around the Earth, the rotation of other planets was Sun-centered. However, Copernicus could not dare to reject the ancient wisdom about crystalline spheres (Gingerich, 1993, p.32). Tycho preferred not to be in contradictory with the Holy Scriptures and so, claimed that the crystalline substance was the invention of the ancients, and not real. Similarly, Ptolemy's equant was also a threat to the crystalline spheres of heaven because it let the interpenetration of the spheres of Mars and Saturn (Gingerich, 1993, pp.31-32). To understand how such a stand could threaten the ancient wisdom, the origins of depicting the spheres as crystalline could be

[67] Also, there was not an agreement on the locations of Venus and Mercury because of the complication about their motion. Some of the astronomers and natural philosophers located both of them above the Sun (Plato), some below the Sun (Ptolemy), and some the mixture of these two, locating Venus above and Mercury below the Sun (Al-Bitruji) (Copernicus, 1992, Book 1, ch.10).

introduced. The ancients believed that the heavenly bodies were composed of a different element called aether or quintessence. This fifth element, in addition to the earthly quartet (earth, water, air and fire), was specific to the heavenly bodies because it was weightless. It was intrinsically luminous and able to emit its own light. Its concentration in heavenly spheres was different, and this caused a division between them as the visible and the invisible bodies (Finocchiaro, 2010, pp.7-8). As a result of this particular composition, heavenly bodies were characterized as hard but smooth and transparent crystals. This aethereal nature was preserved by Ptolemy for epicycles, too. In this picture, the epicycles were made of hard crystal and were gliding without friction in a circular pipe (the deferent) whose crystalline structure was firmer (Gingerich 1993, p.27). The deferent was the orbital path of the planets carried on one or more epicycles, and the center of the deferent was the midway between the Earth and the equant. Because of this model with an unusual center, the deferent was often interchangeably used with the eccentric. Even though the epicyclic structure was fitted into the Ptolemaic picture, other parts of the geocentric model or its partially adapted versions created some problems for the crystalline material. On the one hand, Tycho was contradicting with this model because he let Mars to orbit around the Sun. To be consistent with Ptolemy's mathematical data, Tycho had to depict Mars with two epicycles. While the smaller epicycle was closer to the center of the deferent, the larger epicycle was riding on the smaller one. This organization caused the smaller circle to be cut through by the larger circle, and made the reservation of the spheres as crystalline impossible (Gingerich, 1993, pp.29-30). On the other hand, Ptolemy was contradicting the crystalline nature of the spheres because of the equant. Since the equant was requiring a "mechanical linkage" to keep the planets in uniform speed, its construction in a spherical model "nested one inside another" without cutting through other crystalline material was impossible (Gingerich 1993, p.27). Therefore, neither a completely geocentric model like Ptolemy's nor a semi-geocentric model as Tycho's was able to give the solution that Copernicus desired.

The suggestion of a Sun-centered universe immediately after the rejection of geocentric model requires a detailed explanation here. There are some theories trying to highlight the Sun-worship of Copernicus, which was inherited to him by Neo-Platonists, like the humanist Marsilio Ficino (Koyre, 2009, p.65). The origins of this admiration were the metaphor of the Sun in Plato's *Republic*. In the treatise named *On the Sun*, Ficino argued that the nature of the God could be revealed by nothing but the Sun (Kuhn, 1995, p.131). Even though these lines were not written with a scientific interest, but rather with a literary motivation, their incompatibility with the Ptolemaic astronomy might support Copernicus to envisage a new system centered by the Sun. His reference to the Hermes Trismegistus from astrology to define the Sun as a visible God could be considered as a proof for this intellectual influence (Copernicus, 1992, I,10). Since the idea of heliocentricity was sympathized by Copernicus beginning from the early years of his study, it is important to see that how he rationally linked this enjoyment with the Sun to the justification of his theory.

> He liked the idea of placing the Sun, clearly a unique body among the planets, in a unique central place, and he was impressed by the rhythmic regularity possible with the heliocentric arrangement- hierarchy between planets: the fastest is the nearest- and with the Earth falling in the natural sequence between Venus and Mars (Gingerich, 1993, p.190).

As it is stated earlier, symmetry was an ideal for Copernicus. Thus, he was criticizing the violators of this ideal, which was also known as the axiom of uniformity in Aristotelian physics, harshly. He made an allegory between the destructive modifications of the universe-model and the act of creating a monster. The people like Ptolemy who omitted something essential or added something irrelevant were taking a bunch of well depicted hands, feet, and head from various bodies with the aim of designing a perfect man. However, the result was resembling a monster, rather than a man (Copernicus, 1992, preface, p.4). Copernicus's seek for symmetry and uniformity came to fruition when he recognized that the physical reality of the heavens could be revealed with the motion of the Earth around the Sun, not the reverse. The attribution of the 365-day rotation to the Earth, rather than the Sun, was making more sense for the harmony within the organization of heavenly bodies. This new place of the Earth was fitting nicely to the middle of Venus whose revolution was composed of 225 days and Mars with 687 days (Gingerich, 1993, p.32).

Now, Copernicus was free to claim that "as though seated on a royal throne, the Sun governs the family of planets revolving around it" (Copernicus, 1992, I, 10). The Sun was in the middle of everything. For Copernicus, "this beautiful temple could not be placed in another or better position than this", because at the center of the universe, "it can light up the whole thing at the same time" (Copernicus, 1992, I, 10). Actually, the center of the universe was not the Sun, but rather a point near the Sun. Koestler takes attention to this detail by using Copernicus's metaphor against him. His universe did not have a single royal throne, but rather two: the Sun and the imaginary point in the vicinity of the Sun, which was the center of the Earth's orbit (Koestler, 1959, p.194). Since the center was an intangible point in space, Koestler refers to Copernicus's cosmos as "vacuo-centric system". Even though his system was including some problems about corresponding to physical reality, Copernicus was offering an indisputable geometrical simplicity to explain the retrograde motions of the planets (Koestler, 1959, pp.194-195). They were clarified by the time differences of the planets to complete their orbit. While the Earth was rotating around the Sun with other planets, the Earth was overtaking or passing the outer planets whose speed was slower. Then, these planets seemed to recede and move backwards for a while. This was how a retrograde motion appeared. The same thing was also observed, when the Earth was passed by the inner planets. When their regression ended, they seemed stationary for a while, and then continued to their usual motion. The "marvelous symmetry of the universe" was furnished by the genuine hierarchy between planets and the promotion of the Sun to the center of all their revolutions (Copernicus, 1992, I, 10). Since the Earth was depicted as in motion, and so, became one of the planets, whatever appeared as a motion of the Sun was literally transformed to the motion of the Earth. It was discovered that the Earth's motion was the real cause all of the apparent motions: the daily revolution of the whole firmament, the annual motion of the Sun, seasonal changes, the inequality of days and nights, and irregularities of the length of seasons.

To give a reason for each appearance, Copernicus described three different motions: daily motion, yearly motion, and the motion in inclination (Copernicus, 1992, I, 11). The first motion was the motion of the Earth around its own axis and was describing the equator. It was forming day and night, and causing an impression that the whole heaven was making a revolution completed in one day. The second motion was the motion of the Earth on its orbit, also known as the "orbital rotation" (Copernicus, 1992, I, 4). The Earth was tracing the ecliptic around the Sun, but it appeared that Sun was making an annual revolution in the ecliptic. This was also the real cause of the seasonal changes. The third, and the last motion of the Earth was also known as the "oblique rotation" due to the obliquity of the ecliptic (Copernicus, 1992, I, 4). It was nearly a yearly motion, but it performed in the opposite direction, which was from east to west. This motion of the Earth's axis was creating an image that the Earth was oscillating or wobbling. It was inclining the Earth's angle "not more than 23° 27'" and causing some inequalities of days and nights, and seasonal periods (Rosen, 1971, p.64, footnote 15). Also, this inclination caused a slight variation in the equinoctical points (spring and autumn) -where the ecliptic and the celestial equator intersects- and solstitial points (winter and summer) -where the Sun is at its maximum declination. However, the amount of the variation in the points marking ecliptic in each 90 degrees grew with the passage of time and became more apparent. Therefore, it was mistakenly named as the precession of equinoxes by the ancients.[68] A consequence of the Earth's rotation was

[68] The essential base of Ptolemaic astronomy for measuring the length of the year was the observations of Sun at the equinoxes. By documenting the time passing between the vernal (spring) equinoxes, Ptolemy calculated the tropical year. It was also called as the "natural" or "seasonal" year because of marking four annual seasons (Copernicus, 1992, III, 13). However, Copernicus changed the method of measuring the length of the year and benefited from the lunar eclipses to determine the Sun's position among the stars. This method referring to the stars was called as the "sidereal" year and became 20 minutes longer than the tropical year (Gingerich, 1993, p.20). The sidereal year was calculated as 365 days, 6 hours, and about 10 minutes in *Commentariolus* (Rosen, 1971, p.67). A more exact estimation was managed in *De revolutionibus* as 365 days, 6 hours, 9 minutes and 40 seconds (Rosen, 1971, p.67, footnote 24).

erroneously associated with the motion of the sphere of the fixed stars. So, the astronomers made a futile effort to argue the existence of another surmounting sphere as the ninth, even the tenth sphere (Copernicus, 1992, I, 11).

These changes about the place of the Earth, and the order of the planets had some effects on the scale of the universe. By the time of Ptolemy, the size of the universe was estimated by the help of a "plenum" universe model which gave no place for holes and positioned all spheres side by side (Gingerich, 1992, p.67). For instance, the epicyclic structure belonging to Mars was initiated at the outermost edge of the mechanism defined for the motion of the Moon. Similarly, where the mechanism described for Mercury ended, this of Venus began. For measuring the distances between the spheres, the extension of the Earth, also called earth radii, was used as the reference. The distances calculated brilliantly by this method was also matching to the findings of Aristarchus about the distances of the Sun and the Moon to the Earth (Gingerich, 1992, p.67). Copernicus also reserved Ptolemy's number for the solar distance and calculated the length of the area between the Earth and the Sun as 1200 earth radii. However, the metric of Copernicus's system was entirely different from Ptolemy's. According to Copernicus, the magnitude of the distance between the Earth and the Sun was easily noticed in comparison with the Earth's distance to any other planets (Copernicus, 1992, I, 10). The great circles of the planets, which were the counterparts of what equator meant for the Earth to the planets, were scaled with respect to the Earth-Sun radii. This new common measure of the universe as the Earth-Sun distance increased the gaps between the planets about half as large as they had ever been concerned (Gingerich, 1992, p.67). Still, it was supposed imperceptible when the distance to the sphere of the fixed stars was considered, as it already argued by Copernicus in his *Commentariolus* as the fourth postulate (Rosen, 1971, p.58).

CHAPTER 4

CONCLUSION

As is evident from the survey of the *heuristic* as a notion having diverse definitions and adjustments, it requires an attentive study to be diagnosed thoroughly. It is obvious that there is still much work to be done for sterilizing this problem-solving machinery from its defects and manifesting its jurisdiction more precisely. As a conception which had evolved in accordance with the requirements of Lakatos for improving his methodology, *heuristic* did not complete its transformation yet. What is aimed in this paper is suggesting a new path for the exposition of the *heuristic* as a tool of investigation. The idea is defining the *heuristic* as the interrogative tools of the inquirer, which guides her to find conclusive answers to the questions raised by the problems of her on-going inquiry. These tools are designed to include different groups of questions which are gathered pertaining to the similarities of their role in problem-solving. They can be used either for discovering a research programme or for its appraisal. The service offered by these tools is two-sided. Firstly, they are helping the inquirer to find where to start digging. They are pointing the problems which can turn into anomalies within the research of the inquirer if they are not resolved immediately. Secondly, these tools are reenacting the whole process of questioning that the inquirer goes through for formalizing her ideas. This reconstruction process is enabling the inquirer to express her thoughts intersubjectively. Thus, her study becomes transparent to be criticized and modified properly.

After defining the role of questions within a research programme, a case study is introduced to show how this new path drawn for the *heuristic* is functioning.

Copernicus's heliocentric system of universe is analyzed in the light of questions. His distinctive personality as a revolutionist in the history of science is put under the microscope. His passion for symmetries and aesthetical harmony is traced in order to demonstrate that his socio-economic background is an indispensible part of his cosmology. The historical importance of his birth year, the political view of his relatives, the technical and theoretical innovations in those years, the courses that he took, the books that he read, the schools where he educated, the travels that inspired him, the figures who made an influence on his intellectual development, and the friends that helped him to publicize his revolutionary thoughts are all examined. The aspects that he was distinguished from his predecessors are also questioned. The reason of his success was neither his expertise in mathematics nor his ability in using observational instruments. He did not have a crowd who trusted and supported him either. Even, he was the target of many harsh criticisms coming from the Church or the readers who did not want to conflict with the commonsense. Nevertheless, he achieved to be remembered as one of the great figures in the history of science. His cosmological revolution was "a vision of the mind's eye" and based on consistent theories more than infallible observations (Gingerich, 1993, p.6). What he argued was not purely original, but the way of organizing his ideas and the fluency that he captured within the relations among different sets of data gained him a lasting fame. "He was not an original thinker, but a crystallizer of thought" (Koestler, 1959, p.210).

To "explain the entire ballet of planets", Copernicus build his system on the question of equant (Rosen, 1971, p.20). The elimination of the Ptolemaic instrument, the equant, was the *heuristic* of Copernicus's programme. However, the solution of this problem was not easy, and so, the inquiry of Copernicus had to be divided into sub-inquiries all of which are derived from the same *heuristic*. The principal question was tried to be exposed via small and operative questions. The division of the big problem to its sub-problems eased the task of Copernicus by letting him to solve them one at a time. Through the different stages of his inquiry, the *heuristic* of the programme gave rise to many questions. His questions to find a real clarification for the problem that the equant was invented to resolve was transformed during the inquiry. The rise of new questions to open the clogged roads for the *heuristic* enabled Copernicus to get closer to the discovery of his cosmology. Sometimes those questions helped Copernicus to narrow down his inquiry and to specialize in posing technical questions to receive particular answers. For the other times, he was guided by the questions which were posed with a philosophical stand and so, broadened his perspective. But all the time, the main task of the questions was being helpful to Copernicus to explore all of the possible paths of the inquiry that a *heuristic* could guide.

In its early stages the *heuristic*, or the question of formulating an equant-free cosmology, led Copernicus to inquire a new interpretation of the circles in an agreement with Aristotelian physics. Since the Ptolemy's theory was violating the Aristotelian principle of uniform and circular motion, Copernicus rejected all of the *ad hoc* attempts to modify the current mathematical representation of the heavens. This operative question about the re-arrangement of circles led Copernicus to figure out that the rise and fall of the stars in each 24 hours and the circle of the day and night were just appearances. What made them seem real was the motion of the Earth whose size was much smaller in comparison with the whole firmament. Therefore, Copernicus found the Earth more suitable to the daily rotation. After finding a satisfactory answer to the first question, Copernicus traced the real reason of the violated motions of the planets. When his research was focused on the planetary motions rather than the representation of the whole universe, his inquire narrowed down. He questioned a more specific and technical issue about the retrograde and stationary motions of the planets, especially of Venus and Mercury. The second path that the original *heuristic* was led the inquiry was seeking for a relation or principle which could explain these violated motions. His hypothesis about a mobile Earth incited him to consider it as a planet and re-calculate its place. When the Earth fitted better to the sphere between Venus and Mars, which was the place earlier reserved for the Sun, it became clear that the planets were ordered according to their size. This discovered hierarchy between the planets set the biggest planet, Saturn, to the outermost, and the smallest, Mercury, to the innermost. After the second question was answered, too, Copernicus investigated by what the center of the universe was occupied. Since the total size of the universe was almost duplicated as a result of carrying the Earth away from the center, the scale of the inquiry was increased again. The third path explored by the *heuristic* was seeking for a new center for the universe. The inquiry took the form of a philosophical investigation searching for a distinctive celestial body which had a sufficiently powerful background in literature and mythology to rule the whole universe. The answer was the Sun which was admired throughout the ancient history. After this third question was also matched with a satisfactory answer, Copernicus inquired whether the immobility of the Earth could have other influences on the motions of the celestial bodies. The forth path that the *heuristic* led was investigating whether some other irregularities, too, could be explained with the same source, which was the motion of the Earth. As a result of the attempt to address as many issues as possible with a single explicator, the motion of the Earth was decided also as the cause of irregularities such as the seasonal cycles or the inequalities of days or seasons within a year. The geo-kinetic character of the universe was the answer to all of these related questions. Besides its daily rotation, the Earth was described as having two more rotations which were the annual and oblique rotations. With the help of these there motions attributed to the Earth, all phenomena about the appearances were exhausted. In this way, the principal question of Copernicus, which also composed his *heuristic*, met with a satisfactory answer which was compatible with all other answers given to operative questions.

As is seen in Copernican case, the scientists benefit from the questions in the formation of their research programmes. While they are trying to overcome the problems which their inquiries run into, questions escort the inquirers. The content of this accompaniment varies conforming to the scale of the research. When the investigation of the scientist is “shrunk” and focuses on a specific aspect of the questioned phenomena, the questions are tailored and restricted to a smaller area of the research. Thus, the questions become more detailed and answers can be pointed out more easily. However, sometimes such a construction within the content of questions cannot be achieved because the inquirer wants to look to the questioned phenomena from a broader perspective. When an anomaly cannot be solved within the predicted time, the re-arrangement in the objective lens can be useful. The path for discovery can be extended and the *heuristic* can follow this change by generalizing the operative questions of the inquiry. Therefore, the requirements of the inquirer for formalizing her hypotheses or developing her research programme can be satisfied thanks to the dynamic character of the questions raised by the *heuristic*. For the appraisal, the same process can be traced backwards, and for each criticism the corresponding operative question can be targeted for validity tests. If the related question fails in solving the problem raised by the criticism, it can be subjected to a transformation. If it is not possible and the mentioned question is not helpful anymore to shorten the distance between the inquirer and the answer to the principal question, this question can be abandoned. However, the rest of the questions can remain as the successful tools of the investigation. This discharge and employment cycle of the questions can strengthen the survival ability of the research programmes by reducing the number of anomalies. The more dynamism for the questions derived from the *heuristic* can bring the less tolerance to the anomalies. This is a kind of result which may also please those who advocate the demarcation principle as a part of their philosophical stand.

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APPENDICES

A. TÜRKÇE ÖZET

Bilim ve felsefe tarihi içerisinde sorular, araştırma sürecinde yeni düşünce yollarını keşfedebilmemiz için faydalandığımız araçlar olmuştur. Soruların türlerine dair temel bir ayrım onların ne tür araştırmalara öncülük ettikleri üzerinden yapılabilir. Örneğin "anlam" ile uğraşan sorular çoğunlukla felsefi sorgulamalarla ilişkilendirilirken, "dünyevi gerçekleri" işaret eden soruların bilimsel bir ilgiyle yöneltildiği varsayılır (Uygur, 1964, s.72). Bu sebeple de sorgulanan şeyin "ne olduğuna" dair soruların felsefi bir amaçla sorulduğu kabul edilirken, "nasıl olduğuna" dair yapılan sorgulamaların bilimsel bir güdüye sahip olduğu öngörülür.

Felsefi sorgulamalara verilebilecek en belirgin tarihi örnek Sokratik diyaloglardır. Antik yunanda yaşadığına inanılan Sokrates ismindeki bir bilgenin Atina'nın sıradan vatandaşlarıyla yürüttüğü bu diyaloglar, genellikle "Adalet nedir?" gibi basit bir soruyla başlamaktadır. Sokrates'in daha açıklayıcı olan küçük sorularıyla ilerleyen bu diyalog, vatandaşın en başta kabaca vermiş olduğu yanıtın karşıt örneklerle zayıflatılması, yeni ve daha güçlü yanıtların aranması ve en nihayetinde ise sorgulanan kavrama dair arındırılmış bir tanımla vatandaşın buluşturulmasını amaçlamaktadır. Sokrates'in bu süreçte oynadığı rol doğuma yardımcı olan bir ebeye benzetilmektedir. Kendi doğrularını karşısındakine dikte ettirmek yerine, Sokrates vatandaşa kendi doğrularını keşfetmesi için rehberlik etmektedir.

Sorgulama pratiğinin ilkel formlarından olan Sokratik diyaloglar, çağdaş teorilerce birçok başlıkta eksik görülmektedir. Yapılan eleştirilerin başında ise soru soran ve yanıtlayan kişilerin farklı olmasının, bir tarafın bu süreçten yeni bilgiler elde edemeden ayrılmasına sebep oluşu gelmektedir. Sokratik diyalogda bu taraf, soru soran rolündeki Sokrates'in kendisidir. Diğer bir eleştiri ise soru ve cevap ikilileri arasındaki ilişkinin tekil ve belirleyici olmamasıdır. Sokratik diyalogdaki bir soruya birden farklı cevap verilebilir ve her bir cevap eşit derecede değerli görülür. Felsefi sorgulamalarda bir avantaj olarak değerlendirilebilecek bu özgürlük, bilimsel sorgulamalar açısından kabul edilebilir değildir. Bilimsel araştırma süreçlerinde arzu edilen sorgulama, her bir sorunun tam anlamıyla doyurucu olan yalnız bir yanıtla buluşmasıdır.

Bilimsel alanda yürütülen sorgulamalar her daim epistemik bir değer gözetilerek yapılmaktadır. Diğer bir deyişle, bilimsel sorular yeni bilgiler edinmek üzere yöneltilir. Bu açıdan bilimsel sorgulama, bilim insanı ve doğa arasında oynanan bir oyuna benzetilebilir (Hintikka, 1999, s.140). Bilim insanı doğaya sorular yöneltir ve yaptığı doğal gözlemler sonucunda yanıtlar elde etmiş olur. Her bir yeni soru ve yanıtla, bilimin içsel dinamikleri biraz daha fazla tanınabilir. Masa üstü oyunlarda sırayla yapılan hamlelere de benzetilen bu süreç, Sorgulayan rolündeki oyuncunun Yanıtlayan rolündeki oyuncuya yöneltti̇ği sorularla oyunun başında ortaya konan iddianın onanması ya da çürütülmesini içermektedir. İki oyuncu birbirine rakip oldukları için oyun stratejileri de farklılık göstermektedir. Sorgulayan, Yanıtlayan'dan edindiği bilgiler aracılığıyla başta ortaya atılan iddiaya ilişkin çıkarımlar yapmaya ve en kısa zamanda sonuca ulaşmaya çabalamaktadır. Öte yandan Yanıtlayan, kendisine yöneltilen soruları herhangi bir hileye başvurmadan yanıtlamaya, aynı zamanda da Sorgulayan'ın oyunu başarıyla bitirmesini engellemeye çalışmaktadır. Hintikka, oyun benzetmesiyle açıklamaya çalıştığı teorisini kurarken Immanuel Kant ve Larry Laudan gibi felsefecilerden etkilenmiştir. Kant'a göre sorgulama pratiğinde akıl, dizginleri elinde tutmakta ve doğanın öğreticiliğinden faydalanmak için kendi prensiplerine sahip çıkmaktadır (Kant, 2009, önsöz, B xiii). Laudan'a göre ise bilim, problem çözme pratiğidir (Laudan 1977, s.13). Thomas Kuhn'un bulmaca-çözme benzetmesinden de beslenen bu teori, bilimsel teorilerin başarısını onların önemli problemlere doyurucu çözümler sunma kabiliyetiyle ölçmektedir.

Her ne kadar Hintikka tarafından referans gösterilmese de van Fraassen'ın teorisine burada yer vermek uygun olacaktır. van Fraassen bilim insanlarının yaptığı açıklamaları "niçin" sorularına verilen cevaplar olarak görmektedir (van Fraassen, 1980, s.141). Bu teoriye göre bilimsel sorular üç faktör gözetilerek yanıtlanmalıdır: soru tarafından açıklanması talep edilen "konu", bu açıklamayı verebilecek adayların oluşturduğu "karşılaştırma kümesi" ve bu adaylar arasından seçim yapmamızı sağlayacak bir "alakalılık ilişkisinin" tanımlanması. Örneğin, "Adam neden elmayı yedi?" sorusu, cümle içerisindeki farklı kelimelerin vurgulanmasıyla farklı yanıtlar arar hale gelecektir. "Adam *elmayı* neden yedi?" vurgulu sorusu birçok yiyeceğin arasından neden özellikle elmanın seçildiğini sorarken, "Adam elmayı neden *yedi*?" vurgulu sorusu birçok eylemin arasından neden elmayla yapılanın yeme eylemi olduğu sorgulanmaktadır. Bu doğrultuda, "Çünkü Adam açtı" şeklindeki bir cümle ikinci tarzdaki vurgunun yapıldığı bir soruya yanıt olabilmektedir.

Hintikka'nın sorgulayıcı teorisini incelerken fark edebileceğimiz eksikliklerin başında, tarihsel örneklerin araştırılması için yeterince emek harcanmayışı gelmektedir. Soruların daha ziyade mantıksal şekil ve dilleriyle ilgilenen Hintikka, bilim felsefesini bilim tarihinden yoksun bırakmaktadır. Bu eksikliğin giderilmesi ve soru sorma pratiğindeki gelişimin tarih içerisindeki kimi örneklerin parlatılmasıyla incelenmesi gerekmektedir. Ancak bu şekilde bilimsel teoriler, tarihin muhakemesinden geçerek başarılarını kanıtlayabileceklerdir. Tez boyunca desteklenmeye çalışılacak bu bakış açısı, Imre Lakatos'un "Bilimsel Araştırma Programlarının Metodolojisi" (1978) adlı eserinden esinlenmektedir. Lakatos'a göre bilimsel pratiğin temel hücresi tekil teoriler değil, "araştırma programı" olarak adlandırılan teoriler grubudur. Bu yüzden de bilimsel bir tezin çürütülebilmesi için yalnızca tek bir çelişkili örnek sunulması yeterli değildir. Naif yanlışlamacılığın savunusundaki hata, bilimsel tezleri tekil teoriler olarak görmekten ve onları kolayca çürütülebilir varsaymaktan kaynaklanmaktadır. Çoğunlukla karşısına Karl Popper'ı alan Lakatos, bu naif görüşe karşı bilimsel tezlerin başarısını onların çürütülebilir olmasında aramamaktadır. Bir tezin çürütücü örnekler karşısında gösterdiği direncin de tezin bilimsel niteliğini arttırdığını savunmaktadır. Kısacası bilim insanı yalnızca olumsuz deneyimlerden değil, olumlu deneyimlerden de bilimsel pratiğin işleyişine dair bilgi elde etmektedir (Lakatos, 1981, s.116). Bu şekildeki bir bilim pratiği algısı, bilimsel tezlerin dayanıklılığını onları dogmatik, yani hiçbir şekilde çürütülemez, bir pozisyona sokmadan arttırmaktadır. Lakatos'un teorisinde bilim, gündelik iddialardan ayrı tutulmakta ve tarih içerisinde bir ilerlemeden bahsedebilmek için darbelere karşı güçlendirilmektedir.

Bu yüksek lisans tezinin amacı, Lakatos'un araştırma programları teorisini bilim tarihinde önemli bir örnek olan Kopernik Devrimi üzerinden yeniden tanımlamaktır. Temel olarak Lakatos'un "höristik" kavramı üzerinden gidecek tartışma, bilim insanın problem çözerken başvurduğu rehber niteliğindeki bu metodolojik araca katkı sağlamaya çalışacaktır. Öncelikle höristiğin Lakatos'un teorisi içerisinde yapılan problemli tanımlamaları sunulacak, sonrasında ise bilim insanına araştırma programının temel bir elemanı tarafından sunulan bu rehberlik hizmeti sorular aracılığıyla yeniden inşa edilmeye uğraşılacaktır. Kopernik Devrimi'nin alan çalışması olarak incelendiği bu tez, Kopernik'in güneş-merkezli evren teorisini kurarken sormuş olabileceği soruları ortaya çıkarmaya çabalayacaktır. Yine bu tez, gerek Kopernik'in kendi el yazmalarına başvurarak, gerek ise Kopernik hakkında yazılmış ikincil kaynaklara referans vererek, dünya-merkezli evren teorisinin yıkımıyla sonuçlanacak devrimi başlatan Kopernik'i ve yeni kozmolojisini anlamayı hedeflemektedir. Bu doğrultuda şekillenen tezin ilk kısmı, 16.yüzyılın ekonomik ve kültürel şartlarını, Kopernik Devrimi'nin bilimsel arka planı kadar önemli görmektedir. Bu sebeple, Kopernik'in doğduğu yılın tarihsel önemi, gittiği okullar, eğitimi boyunca aldığı dersler, okuduğu kitaplar, ilham aldığı seyahatler, entelektüel gelişimine katkıda bulunan isimler, düşüncelerini kamuoyuyla paylaşması için onu teşvik eden arkadaşları da Kopernik Devrimi'nin dinamikleri arasında yer almalıdır. Ancak böylesi bir tarih anlatımı sonrasında, Kopernik'in teorileri layıkıyla anlaşılabilecektir.

Tezin ikinci kısmında, höristik kavramına dair belli başlı yapılan tanımlara yer verilmiştir. Bunlardan ilki, Lakatos'un orijinal tanımı olan ve araştırma programına özgü tasarlanmış yöntemsel kurallardan oluşan bir höristiktir. Bu makine temel olarak iki işleve sahiptir: araştırma için hangi patikalardan sakınılacağını ve hangi patikaların izleneceğini söylemek (Lakatos, 1978, s.50). Bunlardan ilki araştırma programının negatif höristiğini oluştururken ikincisi pozitif höristiğini oluşturmaktadır. Negatif höristik, araştırma programına gelen eleştirileri kolay bir çürütmeye sebebiyet vermemek için programın "çelik çekirdeği" olan temel tez ve aksiyomlardan uzak tutmaktadır. Pozitif höristik ise programa dair yapılan eleştirileri, programın bilimsel karakterini korumak üzere "yardımcı kemere" yönlendirmektedir. Buradaki yardımcı tezler, çelik çekirdekteki temel tezleri desteklemekte ve negatif höristik tarafından savuşturulan eleştirileri göğüslemektedir. Araştırma programının sahip olduğu tutarsızlıkların içeriden bir gözle ya da dışarıdan bir eleştiriyle fark edilmesiyle beraber, yardımcı kemer içerisindeki bir değişime, ya da diğer bir adıyla modifikasyona, tabi tutulur. Böylelikle başta "anomali", yani çözülmesi güç kural dışılık, olarak görülen eleştiriler araştırma programı tarafından başarılı bir şekilde açıklanabilir örneklere dönüştürülebilirler.

Höristik kavramına dair yapılan ikinci bir tanım ise onun ileri derecede bir alarm sistemi olduğudur (Newton-Smith, 1981, s.84). Bu alarm sistemi, basit problemleri çözülmesi güç anomalilere dönmeden önce tespit etmekte ve onları "önceden oluşturulmuş bir plan çerçevesinde" uyarlamaktadır (Lakatos, 1978, s.149). Bilim insanın problem çözerken danışabileceği bir plandan mahrum kalması, problemlerin her bir durumda farklı ilkelere sadık kalınarak çözülmesi anlamına gelecektir. Bu yüzden eleştirilerin işaret ettiği problemlerle mücadele edebileceğimiz araçlar, araştırma programı problemlerle karşılaşmadan çok daha önce tanımlanmalıdır. Aksi takdirde araştırma programının temel tezlerini korumak üzere yardımcı tezlerde yapılacak her türlü iyileştirme *ad hoc* bir manevra, yani yalnızca özel bir problemin çözümü için geliştirilmiş bir hamle olacaktır. Bu denli özelleştirilmiş yöntemler diğer problemlerin çözümünde kullanılamayacağı için araştırma programına genel bir rehberlik sunmaktan da aciz olacaktır. *Ad hoc* iyileştirmelerin tespit edildiği araştırma programları, kazara yapılmış keşiflerle ya da içselleştirilememiş eleştirilerle yamanmış sayılacaktır. Problem çözme becerisinde bir ilerlemeye yol açmış görünseler de bu tarz programların gelişimi bozuk ya da "yozlaşmış" kabul edilecektir.

Höristik kavramına dair üçüncü bir tanım ise Lakatos'un erken dönemlerindeki ilham kaynaklarından Macar matematikçi George Pólya'ya aittir. O'na göre höristik, "keşif tekniklerinden oluşan tarafsız bir teori bütünüdür" (Hacking, 1981, s.134). Matematikçilerin pratiğine dayanarak oluşturduğu bu tanımda höristik, bir teze yöneltilen eleştiriler ya da sunulan çelişkili örnekler içerisinde "saklı" olan yardımcı tezlerin, matematiksel bir kanıtı düzeltmek için gün ışığına çıkarılmasını sağlamaktadır. Çelişkili tezlerce verilen örnekler, bu sayede, matematiksel bir kanıt biçiminde savunulan tezin yetki alanını genişletmek için asıl tezi onayıcı örnekler haline dönüştürülmektedir. Karşıt kanıtlarca işaret edilen problemler, temel tezin açıklayabildiği fenomenlerin ya da olguların sayısını arttırmak için *bir süre* hoş görülmektedir. Böylesi matematiksel höristikler, bilim tarihi içerisindeki farklı teorilerin çarpıştırılmasıyla elde edileceği gibi, bilim insanın içsel olarak yürüttüğü sorgulayıcı bir diyalog ile de kazanılabilir (Kiss, 2006, s.306).

Höristiğin üç farklı tanımına başvurduktan sonra kavramın eksikli kalan yanlarına dair savunulabilecek tezlere geçilebilir. Temel olarak anomalilerin araştırma programı içerisinde *bir süre* hoş görülüyor olmasının doğurduğu problemlerdir bunlar. Lakatosa göre bu hoşgörü, bilim insanına çözüm geliştirmek için fazladan zaman tanınması ve hızlıca yapılabilecek bir çürütmenin önüne geçilmesi için savunulmalıdır. Fakat bu durum iki farklı açmaza sebebiyet vermektedir. Öncelikle, anomalilerin araştırma programınca kapsanıyor olması, programın içerisindeki teorilerin temel başlıklar altında gruplanması sürecini karmaşıklaştırmaktadır. Anomalilerin yardımcı teori olmaya aday tezler olarak araştırma programı içerisinde var olmaya devam etmesi, koruyucu kemerin hangi teorilerden oluştuğunun bir türlü kesinleştirilmemesine yol açmaktadır. Anomalilerin bu adaylığını bir neticeye bağlamakla görevli olan höristik ise bunu gerçekleştirmek için yeni teoriler istihdam etmeye çabalamaktadır. Bu iki teori grubu içerisindeki sürekli değişim ve devinim ise araştırma programındaki çelik çekirdek teorilerinin varlığını riske sokmaktadır. Muhtemel bir eleştiriyi göğüslemek üzere hazırda beklemesi gereken höristiğin sabit bir hal alamaması, hangi teorinin hangi grup altında ikame edeceğine dair kanaati muğlaklaştırmaktadır.

Anomalilerin hoş görülmesine dair bir diğer problem ise bilim ve sözde-bilim arasında korunması gerektiğine inanılan sınırın silikleşmesidir. “Sınır çizgisi prensibi” olarak bilinen bu ilke, bilimsel ve nesnel gerekçelere dayandırılabilir olanı, metafizik ve öznel olarak deneyimlenebilenden ayırmayı amaçlamaktadır. Bu prensibin korunumu, Lakatos’un teorisini oluşturan temel tartışma başlıkları arasında yer almasa da, onun teorisine dair yapılan eleştiriler arasında hatırı sayılır bir ağırlığa sahiptir. Eleştiriler temelde, anomalilerin onayıcı örneklere dönüşme ihtimaline sırt çevirmemek için bir süre hoş görülmesinin, araştırma programının bilimsel niteliğinden taviz vermesine yol açtığını savunmaktadır. Lakatos’un bu prensibin korunması için geliştirdiği çözüm ise problem-modifikasyonu süreçlerinde yozlaştırıcı olan anomalilerin araştırma programlarınca istihdam edilmemesidir. Bu yozlaştırıcı etkiyi ölçmek için ise Lakatos, yardımcı teorilerin modifikasyona uğramasıyla sağlanan içeriksel bir gelişimin, bir diğer adıyla deneye dayalı ilerlemenin, olup olmadığına bakmamız gerektiğini söylemektedir. Bu gelişim, teorinin yalnızca modifikasyonları *ad hoc* olmayan şekilde yapmasıyla değil, ayrıca özgün tahminlerde bulunabilmesiyle ölçülecektir (Lakatos, 1978, s.41). Eğer problem-modifikasyonu süreci “ilerletici” ise teorik içerikteki gelişim deneye dayalı gelişimle takip edilecektir. Yani olumlayıcı örneklere dönüştürülen anomaliler araştırma programının teorik yapısını güçlendirirken, programın aynı zamanda isabetli ve daha önceki programlarca yapılamamış tahminlerde bulunabilir bir hale gelmesi gerekmektedir. Aksi takdirde, teorinin ön gördükleri ve deneye dayalı sonuçların işaret ettikleri arasındaki mesafe genişler ve teorik açıklamalar deneye dayalı gelişimin gerisinde kalmış olur.

Lakatos'un bu çözümü araştırma programları metodolojisini daha savunulabilir kılmayı amaçlasa da, onu yeterince güçlendirememektedir. Anomalilerin, "yozlaşan" programlarca barındırılmasa da "ilerleyen" programlarca halen daha istihdam ediliyor oluşu sınır çizgisi prensibini tehdit etmeye devam etmektedir. Örneğin, "ilerleyen" bir araştırma programının yozlaşmasının hangi noktaya kadar hoş görülebileceği net olarak belirtilmemektedir. *Bir süre* şeklinde tanımlanan süreç yeterince belirgin bir zaman aralığı ya da kıstas tanımlamamaktadır. Bu yüzden de bir araştırma programının hangi noktadan sonra terk edilmesi gerektiği konusunda fikir ortaklığına varılamamaktadır. Lakatos bir araştırma programının temel teorilerinin hangi koşullarda terk edilebileceğine dair koşulları tartışmaktan ziyade, bu araştırma programının ileriki aşamalara nasıl taşınabileceğine ve geliştirilebileceğine dair kafa yormaktadır (Larvor, 1998, s.57). Fakat bu yönelimiyle, kendi metodolojisine dair gelen bu tarzdaki eleştirilere cevap verebileceği bir pozisyon geliştirmek konusunda da çözümsüz kalmaktadır.

Tam da bu noktada sorular, höristik kavramının tanımlanmasına katkı koyabilir ve yukarıda tarif edilen eksikliklerin giderilmesine yardımcı olabilir. Bir çeşit transformasyona yani biçim değişikliğine uğrayan soruların, araştırma sürecinin farklı momentlerine uyum sağlayıp sağlayamadıkları gözlemlenerek araştırmacının karşılaştığı problemlerle başa çıkma biçimleri analiz edilebilir. Bilim insanın sonraki adımları, araştırması boyunca yönelttiği sorular incelenerek tahmin edilmeye çalışılabilir. Araştırmayı genişletmek ve perspektifi değiştirmek için yeni soruların eklenmesi ya da sadeleşme için gereksiz olanların elimine edilmesi gibi örneklere bakılarak bilim insanın araştırması sonucunda yapmış olduğu keşfi yeniden inşa edilebilir. Bu doğrultuda, keşif için izlenen sorular tezin gerekçelendirmesi için yeniden canlandırılabilir. Kopernik örneğinde olduğu gibi, Aristo fiziğini korumak üzere Batlamyus'un eş-boyutlusunun (equant) mevcut evren tasvirinden çıkarılması şeklinde tanımlanan höristiğin, Kopernik'in keşif sürecini yönlendiren soruları nasıl doğurduğu izlenebilir. Höristiğin, Kopernik'in sorgulaması neticesinde nasıl dünyanın hareket halinde resmedildiği bir evren modelini doğurduğu, Kopernik'in yönelttiği sorular ışığında açıklanmaya çalışılabilir. Kopernik'in hangi alanlarda sorularına cevap aradığına (astrolojiden mi yoksa astronomiden mi türetildikleri) ya da verdiği cevapların niteliğine (hakiki mi yoksa ad hoc mu oldukları) bakılarak problem-modifikasyon süreçlerinin yozlaştırıcı mı yoksa ilerletici mi olduğuna karar verilebilir.

Bütün bunları alan çalışması içerisinde incelemeden önce, bilimsel devrimden kastın ne olduğu ve Kopernik'in neden böylesi bir devrimin öncüsü olarak tasvir edildiğinin açıklanması yerinde olacaktır. Öncelikli olarak belirtilmelidir ki bilim tarihi boyunca hiçbir devrim saniyeler içerisinde gerçekleşmemiştir. Bu yüzden de bilim tarihçileri herhangi bir tarihsel uğrağı bilimsel devrimin gerçekleştiği an olarak tanımlamaktan çekinirler. Kopernik örneğinde de olduğu gibi devrimler, tek bir olay ya da kişinin tekeline alınamayacak kadar çeşitliliği barındıran bir bilgi birikimini gerektirir. Kopernik Devrimi her ne kadar Kopernik tarafından başlatılsa da, geliştirilip olgunlaştırılması sürecinde Kepler, Galileo ve Newton gibi birçok bilim insanı önemli roller oynamıştır. Bilimsel devrimlere dair bir diğer yanılgı ise dönemin devrimci düşüncelerinin birçok çağdaşı tarafından dikkat gösterilmiş ve tartışılmış olduğudur. Sanılanın aksine, birçok devrimci düşünce dönemin diğer düşünürlerince duyulmamıştır bile. Kopernik'in teorisi Newton'a kadar tehditkar dahi algılanmamıştır. Hatta meşhur eseri *De revolutionibus* yorucu teknik detaylarından ötürü "kimsenin okumadığı kitap" olarak nam salmıştır (Gingerich, 2004, önsöz, ix). Bilimsel devrimlerin yanlış bilinenlerine dair verilebilecek son örnek ise devrimcilerin tamamıyla nesnel koşullar sonucunda sivrilmiş olmasıdır. İşin bu kısmının bir haklılık payına sahip olduğu gerçeği göz ardı edilmeden belirtilmesi gereken bir nokta vardır. Tarih içerisindeki kimi olayları anlatırken bir çeşit "aşılanmış" öykülemeden faydalanırız. Bir bilimsel devrimde merkez olarak kabul edilen kişi ve pratikleri resmederken kaçınılmaz bir şekilde kişisel bakış açımızı öyküleyişimize yediririz (Shapin, 1996, p.10). Tarihin günümüzde yeniden, fakat farklı yöntemlerle inşa edilmeye çalışıldığı uğrakları, bizlerin bir gerekçeyle ilgilendiği ve sivrilttiği örneklerin neden olduğu değişimleri anlatmaktadır. Bu yüzden de Kopernik'in öncesinde yaşamış ve benzer iddialarda bulunmuş düşünürlerin değil de, özellikle onun güneş-merkezli evren teorisinin öncüsü olarak resmedilmesi biraz da böylesi bir öykülemeden kaynaklanmaktadır.

Kopernik'in entelektüel gelişimine yardımcı olan sosyal, kültürel, politik ve ekonomik faktörleri göz önünde bulundurarak güneş-merkezli teoriye baktığımızda, onun antik yunandaki mitolojik tasvirlerden, Pisagorcu öğretiden, Arap astronomlardan ve daha birçok farklı kaynaktan beslendiğini görebiliyoruz. Simetri arayışının bir ideal haline gelmesi, Güneş'e duyduğu hayranlık ve Aristo geleneğine olan sadakati, bu tarz etkileşimlerin temel göstergeleri arasındadır (Gingerich, 1993, Koyre, 2009, Goddu, 2010). Yine de Kopernik'in dünyanın hareket halinde olduğu ve Güneş'in merkezde tarif edildiği kozmolojisinin keşfi, güçlü bir höristiğin tanımlanmasıyla mümkün olmuştur. Göksel cisimlerin dairesel ve düzgün hareketinin Batlamyuscu alet ile ihlal edilmesi Kopernik'in başlıca problemidir ve bunun çözümü için geliştirdiği rehber, O'na yeni bir evren algısının kapılarını açmıştır. Tezin bundan sonraki toparlayıcı kısmında, bir höristikten nasıl alt sorgulamalar türetildiği ve bu sorgulamaların Kopernik'in temel sorununun çözümü için nasıl yardımcı olduğu anlaşılmaya çalışılacaktır. Bunun için ise, Kopernik'in teorisi sorular yardımıyla yeniden inşa edilmeye uğraşılacaktır.

Kopernik'in yeni bir kozmolojinin keşfiyle sonuçlandığı sorgulamasında yönelttiği ilk soru, Batlamyus'un equant ismindeki matematiksel aletinin geçerliliğine dairdir (Rosen, 1971, s.20). Gezegenlerin hareketini tanımlamak için geliştirilen bu alet, gök cisimlerinin izlediği yolun merkezini eş uzaklıktaki iki nokta üzerinden tanımlamaktadır. Merkezinde dünyanın bulunduğu matematiksel temsilde dairesel ve düzgün bir hareket yaptığı gösterilemeyen gezegenler (özellikle de Venüs ve Merkür), Batlamyus'un kozmolojisinde iki farklı noktaya referansla modellenmektedir. Biri dünya diğeri de herhangi fiziksel bir cisimce işgal edilmeyen hayali bir nokta olan equant ile tanımlanan düz bir hattın tam ortası, gezegenlerin izlediği yolun merkezine denk gelmektedir. Kopernik'e göre bu modifikasyon gök cisimlerinin hareketlerini iki farklı merkeze göre tanımladığı için Aristo fiziğinin prensipleriyle çelişmekteydi. Aristo fiziğini yeniden güvenilir bir pozisyona yükseltmek için Kopernik, Batlamyus'un on üç yüzyılı aşkın otoritesini sorgulamaya başlamıştır. Kopernik'e göre Batlamyus'un çözümü ne yeterince keskin ne de yeterince akla yatkındır. Rakamsal veriyle uyumlu olsa da, Ptolemy'nin çözümü fizik kurallarıyla çelişmektedir. Gök cisimlerinin eterden oluşan doğasına aykırı bir mekanizma sunan Batlamyus, gök cisimlerinin gerçek hareketlerini açıklamaktan çok onların kağıt üzerinde matematiksel olarak yeniden üretilmesine kafa yoran bir astronom olarak değerlendirilmektedir. Bu yüzden de Batlamyus'un equant ismiyle sunduğu teorisi, Kopernik tarafından *ad hoc* bir manevra olarak değerlendirilmektedir.

Höristiğin equant'ın elimine edilmesi olarak belirlendiği Kopenikçi güneş-merkezli programın erken dönemi, temel olarak dairelerin daha akla yatkın bir organizasyonunu bulmak üzere yürütüldü (Rosen, 1971, s.57). Bu doğrultuda Kopernik, tüm gökyüzünün Güneş'in hareketine bağlı bir hareket içerisinde mi olduğunu yoksa dünyanın hareket halinde olmasının tüm gökyüzünü dönüyor gibi mi gösterdiğini sorguladı (Copernicus, 1992, I, 5, 8). Sonuç olarak ise yirmi dört saatte bir değişime sebep olanın gökyüzünün hareketi değil, onun içerisinde çok daha küçük bir yer kaplayan dünyanın hareketi olduğuna karar verdi. Aynı höristikten türetilen bir diğer sorgulama ise neden gezegenlerin düzgün ve dairesel hareketi ihlal ettiğine dair o zamana kadar yapılmış herhangi bir hakiki açıklamanın olmayışıydı. "Tersine" (retrograde) ve "durağan" (stationary) hareketler olarak tanımlanan bu ihlaller, Kopernik tarafından dünyanın hareket ediyor olduğu keşfiyle sonrasında açıklanmaya çalışıldı (Copernicus, 1992, önsöz, s.5). Dünyanın hareketinden dolayı diğer gezegenlerden farkı kalmayışı ve yerinin Venüs ile Mars arasındaki çembere taşınması çözüm için yeterli bilgiyi sağlıyordu. Gök cisimleri arasında tanımlanan hiyerarşi sayesinde, gezegenlerin takip etmesi gereken patikalar arasında bir uzunluk farkı öngörülüyordu. Gezegenler evrenin merkezinden uzaklaştıkça daha uzun patikalara sahip oluyorlardı ve bu farklılık kimi zaman gezegenlerin tersine kimi zaman ise durağan bir hareket yapıyormuş gibi gözükmesine sebep oluyordu.

Dünyanın merkezden alınması sonucunda yeni bir soru ortaya çıkmış oldu: Evrenin merkezinde hangi cisim duracaktı? Gökyüzü içerisinde ayrıksı ve kuvvetli bir cisim arayışına giren Kopernik, Güneş'i "kraliyet tahtında oturuyormuş" gibi tasvir etmesiyle yanıta ulaşmış oldu (Copernicus, 1992, I, 10). Güneş'in evrenin merkezinde tanımlanmasıyla beraber gökyüzündeki diğer tüm eşitsizliklerin, aslında görüntüde eşitsizlikler olduğu açıklanmış oldu. Buna sebep olarak ise Güneş'in etrafında hareket halinde olan dünya idi. Bu tasvir sonucunda, dünyanın günlük hareketine ek olarak iki farklı hareket daha tanımlandı. Dünyanın Güneş etrafındaki yıllık hareketi, dört ayrı mevsimin bir yıl boyunca birbirini takip etmesinin açıklaması olarak sunuldu. Yıl boyunca değişiklik gösteren gece gündüz süreleri ve mevsim uzunlukları ise dünyanın eğik hareketiyle açıklanmaya çalışıldı. Yıllık hareketle hemen hemen aynı sürede tamamlanan ancak yön olarak tersine gerçekleşen bu hareket, dünyayı yaklaşık olarak 23 derece 27 dakikalık bir açıyla eğmekteydi (Rosen, 1971, s.64, dipnot 15).

Kopernik Devrimi alan çalışmasında da örneklendiği üzere, bir araştırma programının höristiği, araştırmayı yürüten bilim insanının temel ve büyük sorusu olarak tasvir edilebilir. Böylesi güçlü bir höristikten türetilen küçük ama çalışılabilir sorular ise bu büyük sorunun yanıtlanması için araştırmayı yönlendiren yardımcı faktörler olarak değerlendirilebilir. Yöneltilen soruların kimi zaman özelleşerek araştırmayı konu açısından daraltması, kimi zaman ise genelleşerek araştırmanın odağında bir genişlemeye yol açması, höristiğin işleyişiyle alakalıdır. Soruların böylesi bir devinim içerisinde olması, karşılaşılan problemlere daha uyumlu çözümlerin geliştirilmesini ve araştırma programının daha güçlü bir hale gelmesini sağlamaktadır. Höristikten türetilen soruların dinamik yapısı, araştırma programının anomalilere yönelik gösterilen hoşgörüye daha az ihtiyaç duymasını sağlayacaktır. Bu tarz bir sonuç, sınır çizgisi prensibini gözeten düşünürlerin de memnun kalabileceği bir höristik formunu daha imkanlı kılabilir.

B. TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

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YAZARIN

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Adı : Altuğ
Bölümü : Felsefe

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TEZİN TÜRÜ : Yüksek Lisans ■ Doktora □

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