Philosophical Perspectives on Sciences

Hypothesis in science.

The 550^{th} anniversary of the birth of Nicolaus Copernicus

October 19-21, 2022, Toruń, Poland

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Introduction

It is sometimes assumed that the heliocentric (Copernican) and geocentric (Ptolemaic) systems were considered to be equally valid for a long period of time. On the contrary, there are descriptive, and (at least in part) predictive differences between the two models. These differences became even more substantial after the discovery of the telescope. The availability of considerably more new observations and data forced astronomers to abandon the Ptolemaic system, which was no longer able to justify certain physical observations. Rather than the geocentric, it was the geo-heliocentric model (proposed by Tycho Brahe) which became the real antagonist to heliocentrism, since the latter model was able to justify the motions of celestial objects based on observational evidence. However, for geometric description to also provide an explanation, astronomy needed to change its disciplinary goals. This happened when Newton proposed universal gravitation as an explanation for Kepler's elliptical orbits. When Kepler's description of these orbits was combined with Newton's explanation, the geo-heliocentric model lost even more explanatory power, while the heliocentric model was reinforced.

If certain astronomical models and their equations can provide nothing more than an empirical description of the *explanandum*, then one may seek to provide the answer to the following question: could it be that in the geometrically-based astronomical models mentioned above there is something that helps us to distinguish merely descriptive from explanatory models? Since mathematical dependencies of scientific theories do not necessarily specify the causal dependencies that produce the *explanandum*, we probably do not know whether our hypotheses correctly describe the world. Thus, those hypotheses are nothing more than useful tools with which to organise observational data. However, just because a certain model or hypothesis is non-explanatory does not necessarily mean that it cannot play any descriptive or predictive role. What criteria do we have then to evaluate our scientific hypotheses, models or theories?

Our conference aims to address the role of hypothetical thinking in the formulation and development of scientific theories and models. More specifically, studying the role of hypothesis in the sciences could prompt at least three different investigations:

- One might investigate the methods and the forms of reasoning implicit in the work of scientists with the objective of determining how they had relied on hypotheses in their work.
- One might discuss how systematic inquiry into the natural world should be carried out and what role creating hypotheses played for practitioners of sci-

ence.

- One might evaluate the ability of hypotheses to imagine and foresee new phenomena by considering their use as a form of inquiry that seeks to go beyond the immediately observable to the causal structure responsible for observed phenomenon.

Next year will mark the 550th anniversary of the birth of Nicolaus Copernicus. We think that it would be highly pertinent to discuss how our understanding of the role of hypotheses has changed since his time. Is the use of hypotheses still viable in current science, or has it been superseded by other scientific concepts or methods? The aim of our conference is to contribute to the dialogue between scientists, historians of science, philosophers of science, and logicians interested in scientific methods of reasoning.

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Part II.

Invited Lectures

Rationality, Hypotheses, and the Explanatory Power of Modern Physics

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In this talk I will argue for several points. First, I will argue that making hypotheses is not distinctive to scientific thought, but is an intrinsic and necessary feature of human rationality in general. Following Bernard J.F. Lonergan, I will distinguish between the non-rational mode of knowing (which Lonergan called "animal extroversion") that humans have in common with lower animals, and rational cognition, which has the three-tiered dynamic structure of Experience, Understanding, and Reflection. Hypotheses are a part of the second level, where insights into the data of experience are achieved and formulated in terms of concepts and propositions, the adequacy and truth of which are then weighed and judged at the third level, reflection. Rational knowledge only comes at the point of rational judgment of the truth of propositions. I will argue that all rational knowledge, even the most ordinary knowledge of everyday life, arises through the same dynamic process, which involves the making of hypotheses. The cosmologist Andrei Linde wrote, "I know for certain that my pain exists, my 'green' exists, my 'sweet' exists; ... everything else is a theory." He is right, except that some of those "theories" can also be known to be true with virtual certainty through investigation and rational judgment.

Second, I will argue that the most distinctive aspect of the physical sciences since Newton is that its hypotheses are based on the existence of laws that are (a) universal, (b) mathematical, and (c) exact. *Models* are always approximate, whereas the *fundamental laws* are presumed to be exact.) I will discuss the role that all three of these features play in the spectacular success of the physical sciences. I will discuss how, prior to the Newtonian revolution, the value of mathematics in the physical sciences was not understood, because of the influence of Aristotelian ideas about the nature of mathematical abstraction and the nature of quantity, which was associated with the level of "accidental" aspects of things rather than with their essences and causes. Thus, mathematical analysis was seen as irrelevant to such questions, for example, as whether the earth or sun are actually in motion. I will explain how Newtonian physics showed that an analysis based on mathematical theories of physics can yield not merely quantitative descriptions of phenomena, but also explanations that get to the level of causes, essences, and what is *physically* going on. This will involve a more general discussion of the difference between merely descriptive schemes and explanatory schemes. Finally, on this basis, I will argue that the advance of theoretical physics has given us ever deeper and more comprehensive explanations of physical reality as it is in itself.

Osiander and Hypotheses

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Andreas Osiander provides a useful starting point for reflecting on the value of hypotheses. Many are aware that Osiander was the author of "*Ad lectorem*", a letter placed before the Preface of Copernicus' book, *De revolutionibus orbium coelestium.* As a consequence of this, Osiander was responsible for a particular reading of Copernicus' book, an instrumentalist reading, which was central to the Wittenberg Interpretation. Not as many are aware that Copernicus and Osiander corresponded two years before the book was published. In this exchange, Osiander shared his views on hypotheses with Copernicus.

Being now in Toruń, where Copernicus was born, and invited to discuss the role and importance of hypotheses in science, it is fitting to examine Osiander's views on hypotheses. Osiander's views are of more than just historical interest. I argue that Osiander draws attention to aspects of hypotheses that continue to deserve our attention. Osiander draws attention to both (i) evidential considerations and (ii) sociological considerations. Both of these types of considerations have epistemic import. Osiander is also most clear about what instrumentalism entails. He thus provides some insight into the nature of instrumentalism as an account of scientific hypotheses and theories. Osiander provides us with an opportunity to see what a truly interesting instrumentalist view might look like.

Newton's Hypotheses in the Proof of the Copernican System

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Isaac Newton's proof of the Copernican system is a very well-researched topic, and for very good reasons: it is the argument that—according to a standard narrative—crowned the Scientific Revolution, bringing the great Copernican debate opened in 1543 to a close in 1687. This argument, especially through the notions of absolute and relative time and space, immediately aroused sharp and deep criticisms from the likes of Christiaan Huygens and Gottfried Wilhelm Leibniz. Albert Einstein redrew the edifice of physics from scratch in such a way as to make Newton's approach obsolete. In this paper, I will not review the vexed question of absolutists versus relationists, opened by Huygens and closed by Einstein (again according to a somewhat standardized narrative). My aim is to consider the role played by two hypotheses, which are crucial for Newton's argument. In conclusion I will weigh up how these hypotheses are viewed by the sociologist, the philosopher, and the historian of science.

Weaving Hypotheses Into Knowledge Threads

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Dynamics of scientific knowledge is often conceived in philosophy as driven by advancing new hypotheses. There are alternative approaches to account for this role which may be grouped into 1) deductivist, 2) cognitivist and 3) evolutionary. A short exposition is followed by a more detailed elaboration of an evolutionary approach propounded here in terms of "knowledge threads". Campbell initiated the evolutionary approach to science dynamics in terms of blind variation and selective retention model (BVSR). However, to think of hypotheses and new ideas in science as generated "blindly" is apparently counterintuitive. First, what needs to be accounted for is the kind of heuristics adopted in research, such as novel or breakthrough, that determines the kind of hypotheses which are desired. Second, hypotheses as genuine projections of the existing body knowledge need to be distinguished from mere speculations. To illustrate the distinction, I use an example based on Goodman's theory of projections. Next, I discuss the key components of empirical grounding that transform hypotheses from projections into an established body of knowledge. With the proposed modifications the original BVSR model turns into "heuristics-driven variation" (HDV) selective retention model proposed here.

Simonton exposed a markedly Cartesian twist to the original Campbell's BVSR where new "variations" turn out to be simply recombinations of pure ideas out of the blue sky. In other words, the other main weakness of the original evolutionary approach – as well as of the traditional philosophical accounts, such as neopositivistic or Kuhn's – was ignorance of, widely speaking, the institutional context within which scientific hypotheses are originated and tested. This deficiency has been amply exemplified by social studies of science since 1980's onwards. It is selective retention of scientific knowledge where the social aspects of knowledge generation come to the fore. I draw upon Twardowski's phenomenological distinction between knowledge as output contrasted with act to elaborate a concept of *knowledge thread* as an alternative to the widespread Cartesian compositional concept of knowledge as a mental state (esp. JTB account). The concept of knowledge thread yields the epistemological rationale for the integration of the two components of knowledge dynamics in the HDV-SR model, namely cognitive and social.

In the final part the logic of the proposed HDV-SR model and the proposed concepts related to knowledge dynamics are exemplified with a detailed examination of one of the recent breakthrough discoveries in molecular biology, to wit, microRNAs.

Idealizations in Explainable AI

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xAI models seek to explain how a more complex black-box ML works. xAI models have been criticised for being inadequate because they do not have complete fidelity to the truth. However, it is not falsehoods simpliciter that is a problem, but idealization *failure*. In this talk I discuss how we might be able to evaluate the success of idealization in xAI and how current xAI models fare on these metrics. I also suggest possible remedies for various kinds of idealization failures.

Identifying Future-Proof Science

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Some scientific ideas make a transition from speculation, to hypothesis, to well-supported-theory, to fact. Clearly this happened for the basic Copernican claim that the Earth turns on its axis and orbits the Sun. There are many other examples, and nearly all so-called ‘anti-realists’ will accept many of the examples just as much as so-called ‘realists’; very few philosophers doubt that smoking causes cancer, or that contemporary global warming is anthropogenic. But to-date there is scant scholarship on the topic of *when* we should say that a scientific claim has become an established scientific fact. The renowned evolutionary biologist Ernst Mayr “often deplored that he was not aware that philosophers of science have investigated this transition from theory to fact” (Hoyningen-Huene, 2022). Recently, IPCC report writers have sometimes struggled with the same issue; one such writer recently asked, “Where is the boundary between “established fact” and “very high confidence”?’ (Janzwood 2020). For both scientific and political reasons, IPCC authors really need to know where this boundary lies. Or, if there is no boundary as such, they need at least *sufficient* conditions for when something can be called a ‘fact’.

In my new book Identifying Future-Proof Science (2022), I tackle this question head-on. Building on Oreskes, Why Trust Science? (2019), I argue that one determines an established fact not by looking at the science, but, rather, by looking at certain features of the scientific community (second-order, not first-order, evidence). I argue that a fact can be identified when there is a 95% consensus within a scientific community that is large, international, and diverse, and where that consensus has been reached through bona fide scientific activity (thus ruling out tacit background assumptions).

One may worry both that (i) the criteria can be met for something that is not a fact, and also (ii) the criteria might not be met for something that is a fact. Regarding (i), phenomena such as ‘groupthink’, the bandwagon effect, or perhaps ‘paradigm indoctrination’ could, in theory, lead to a strong scientific consensus for all the wrong reasons. Regarding (ii), one may worry that the basic Copernican hypothesis didn’t meet the criteria until relatively recently, when scientific communities became somewhat ‘diverse’ — surely an unpalatable conclusion.

Part III.

Contributed Lectures

Mechanistic Constitution and Hypothetical Reasoning

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In 1971, John O'Keefe and Jonathan Dostrovsky broached the hypothesis that the hippocampus is a cognitive map. From this seminal work, O'Keefe built a research program that led to his being a co-recipient of the Nobel Prize in 2014. In this body of research, the hippocampus was an observed neuroanatomical structure, but its function as a cognitive map was not observed at all. We propose that O'Keefe overcame this, and other observational limitations, by using a kind of hypothetical reasoning we call "mechanistic constitutive abduction." A common way of understanding abductive reasoning in general is that it is reasoning that confirms some hypothesis, because of what that hypothesis explains. According to Magnini, abduction is "inference to an explanatory hypothesis" (Magnani, 2001, p. xxi.); According to Aliseda, abduction is "reasoning from an observation to its possible explanations," (Aliseda, 2005, p. xii). Sometimes this reasoning is unpacked as follows: If H were true, then H would explain E, so we have reason to think that H is true. In the general description of abduction, one leaves unspecified what one understands by an explanation. We propose that, in a mechanistic constitutive abduction, the explanation is a mechanistic constitutive explanation. See, for example, Craver, 2007. During the 1930's, Edward Tolman ran experiments that led him to propose that rats navigate mazes using cognitive maps, rather the stimulus-response strategies. (See, for example, Tolman, 1948.) Simplifying a bit, in 1971, O'Keefe and Dostrovsky observed that certain hippocampal cells (later called "place cells") were responsive to a rat's orientation and location on a platform. Piecing their results together with Tolman's, they formed two hypotheses: 1) the firing activity of place cells mechanistically constitutes the mapping computational activity of the hippocampus and 2) the mapping computational activity of the hippocampus mechanistically constitutes the navigational activity of the rat. They predicted that one might further confirm these hypotheses by showing how they would explain various experimental results. Much of O'Keefe's subsequent research was dedicated to showing how the two hypotheses would mechanistically constitutively explain experimental results.

On Hypothesis Refinement by Existential Instantiation

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In this presentation I shall focus on a particular process of hypothesizing, one which I label hypothesis refinement by existential instantiation. The point of departure is an existential statement which may be a product of abduction itself, that is, the postulation of an entity (an object, a phenomenon) that would explain an otherwise anomalous observation. The refinement then consists in an instantiation of the initial existential statement, so that a specific entity is recognized. In the history of science as well as in scientific practice there are several cases of this kind of hypothesizing. A remarkable one is the discovery of Neptune. A significant deviation of planet Uranus' orbit from the predicted orbit, detected by When Adams and Leverrier in 1846, was explained by the postulation of existence of another planet. Indeed, the existence of Neptune was postulated with a definite location, showing that the two steps —postulation and instantiation— were really one. Further observations corroborated Neptune's existence as predicted. Other cases are not so straightforward, such as that found in the debate on dark matter. The original idea by Zwicky in 1933 was that there was not enough ordinary matter to hold galactic clusters together. Therefore, he postulated the existence of dark matter to account for it. Here is an existential statement with no precise proportion neither exact location of such dark matter. Later on, observations of an expanding universe plus anisotropies in the cosmic microwave background radiation led Robin in 1980 to instantiate that existential hypothetical statement as follows: there's 95% of the total divided up between 70% of dark energy and 25% of dark matter, leaving 5% to ordinary matter. Therefore, in this case, there was a process of hypothesis refinement from "There exists dark matter" to "there is a proportion of 25% of dark matter". More generally, in this presentation hypothesis refinement by existential instantiation will be defended as a case for progress is science, for an existential instantiation improves an existing theory. Still, even if there is a process of refinement it is not until the hypothesis is corroborated when a genuine scientific progress is made.

Galileo on Faith and Reason

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The scientific claim of Galileo that the Earth revolves around the sun specifically challenged the theologians during his time since Galileo's position would challenge the literal interpretation of Joshua 10 that states the sun was mobile but then became immobile. Instead of claiming that Scripture is erroneous, Galileo argued that science can assist in interpreting scripture and is compatible with faith. For this reason, Galileo tried to use science to correct the interpretation theologians had at the time about Joshua 10. However, although Galileo tried to convince the theologian, Galileo's insight on Joshua 10 was not convincing since Galileo did not have the demonstrations to prove his claim. For this reason, I argue that Galileo, instead of arguing that science can correct the interpretation of scripture, Galileo should assert that scripture is only concerned with theological matters and science with things of the world. If Galileo asserts the latter, then he has full support from the Apostolic and Church Fathers, Medieval Philosophers, and even Contemporary Theologians.

Hypothesis: A Methodological and Personal Tool in Developing Dcientific Theories

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In the formulation of scientific theories and models, the hypothetical reasoning is still today a fundamental and irreplaceable tool founding the hypothetical-deductive method. As K. Popper and M. Polanyi have pointed out, the hypothesis takes on a defining role particularly in the "context of discovery". Considering the methodological aspect, the hypothesis must not be considered apart, on the contrary it must be fully integrated into the cognitive process: on one hand, hypothesis starts from a collection of data, from the careful observation of a certain phenomenon or type of problem for which a valid explanation or solution has been found. On the other hand, the hypothesis is an attempt to be tested in practice: it is an idea that must pass from theory to empirical verification of facts. Therefore, the hypothesis is intrinsically transient, as a tool to be used to build up a scientific theory which, if corroborated by experimental results over time, no longer remains a hypothesis, but becomes the basis of a theory which explains an aspect of reality. Otherwise, if the hypothesis doesn't work, it must be eliminated and replaced by other ones.

Moreover, the hypothesis, besides occupying a crucial role, has a particular nature, which escapes the pure logical-scientific rationality: the hypothesis is often the fruit of a metaphysical vision, or at least brings with it elements not properly belonging to the rational sphere. Polanyi (1891-1976) focused on the "personal component" that affects the cognitive process in a unique decisive way: the hypothesis is the result of the scientist's previous knowledge and experience as well as his general way of thinking and seeing reality, *i.e.*, his "cosmovision" (*worldview* or even "*weltanschauung*"). Therefore the hypothesis is part of the cognitive act which, without being irrational, comes out from imagination and 'creative intuition' proper to human act as a whole (M. Polanyi, *Personal Knowledge Towards a Post-Critical Philosophy*, 1958).

Epistemological Status of Fundamental Principles in Science With Applications to Rationality in the Social Sciences

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Fundamental principles are hypothesis of a singular epistemological status. As Imre Lakatos argued, they are part of what he called the hard core of research programs, which is a set of hypothesis, definitions, . . . rendered irrefutable, protected by a belt of auxiliary hypothesis. That is, each time a contradiction between theoretical expectations and experience appears, the modus tollens will be directed towards some auxiliary hypothesis and not towards the statements in the hard core. They are not directly falsifiable in a popperian sense. Their epistemological status is then not obvious. Following Lakatos, I argue that fundamental principles which compose the hard core of a research program are not judged directly at the light of their direct empirical (dis)confirmation but rather with respect to how much they can accomodate empirical anomalies and generate discoveries. For a mature theory, the epistemological value of fundamental principles is then related to their capacity to (non trivially) explain a wide range of phenomena from a minimal number of basic assumptions. An example of such fundamental principles is the principle of rationality in the social sciences. This kind of principle is highly related to methodological individualism, a framework the aim of which is to explain macrosocial phenomena by the aggregation of micro (i.e. individual) decisions and behaviours. Rationality principle is a way of implementing this idea, saying that a theory of human action has to rationally reconstruct the behaviour of individuals. Important criticism of such research programs come from the fact that they seem to be irrealistic, since we know from cognitive and social psychology that humans often fail to reason and act rationally — and it seems problematic for a social theory to rest on an irrealistic theory of action. In the light of the previous reflections, I would like to wonder whether a rationality principle should be viewed only as a mere guiding hypothesis, an irrealistic but useful model (as the Bohr's model of atom) or if it could enjoy a more robust epistemological status. Concrete examples from physics, economy and sociology will support these reflections.

Epistemology of Computer Simulations in Biology

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Biology is a paradigmatic example of use of scientific models. The models serves as the basis for simulations. As a consequence, computational modeling in biology plays the typical cognitive functions explaining with models and understanding with models. Simulations could play a role of additional step in formulation of the theory, distancing theory from reality from the epistemological point of view. However, due to role of modeling, simulations could be almost theory-independent. Computer simulations in biology challenges the problem of complexity and computability. The complexity of living organism is manifested *inter alia* in the problem of epistemological and/or ontological levels of analysis. Focusing only on one level of abstraction, means the idealization, however this enables in practice computational modeling. Simulations opens new field in biological research — biology *in silico*, which creates and explores simulated life-like phenomena. System approach were used as a basis for computational modeling of alive units. This approach is close to cybernetics. In particular, the problem of the adequacy and interpretation of the results obtained in experiments and observations in subcellular biology is an important issue related to modeling in biology. The problem is weighty and epistemologically fundamental, but so far it has not raised any response in the milieu of biologists. Adequate modeling of biological processes, especially in the context of their functions, allows to supplement the results obtained on dead tissues by electron microscopy, and by observing subcellular processes *in vitro* and *in vivo*, which inevitably disturb these observations. the process itself. The complementary use of the above four techniques allows for an attempt to obtain knowledge that is significantly more complete than using each technique separately.

Theoretical Approaches for Biological Structures Understanding

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Pathogenesis-related proteins of class 10 are among the most curious plant proteins because no unique function can be attributed to them despite their high levels of expression and involvement in other processes. I will present our theoretical methods which allowed for description of their features. To fully understand protein dynamics we have to analyze their creation process. Proteins are created by ribosome which is a biomolecular nanomachine that performs protein synthesis at its peptidyl-transferase center (PTC) as directed by an mRNA template. I will present our studies on the nascent behavior of three model coarse-grained proteins in six rigid all-atom structures representing ribosomes that come from three domains of life. The synthesis of the proteins is implemented as a growth process. The geometry of the exit tunnel is quantified and shown to differ between the domains of life: both in volume and the size of constriction sites. This results in different characteristic times of capture within the tunnel and various probabilities of the escape. One of the proteins studied is the bacterial YibK which is knotted in its native state. A fraction of the trajectories results in knotting and the probability of doing so is largest for the bacterial ribosomes. Relaxing the condition of the rigidness of the ribosomes should result in a better avoidance of trapping and better proper folding. At the end, I will show how our molecular dynamics simulations were useful in description of mechanical stability of SARS-CoV-2 virus and its impact on the increasing spread of COVID-19.

Hypothesis and Consilience in the Nineteenth Century

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Perhaps the most important development in nineteenth century philosophical discussions on scientific methodology was the dynamic re-emergence of the method of hypothesis. Nineteenth century philosophers— especially the ones sensitive to the complexities of scientific practice as demonstrated also by the study of the history of science—started to realize that traditional scientific methodology, which regarded scientific inferences as inductive generalizations from empirical facts, could not accommodate the new scientific developments, particularly those related to the investigation of unobservable entities and phenomena (Laudan 1981). Amidst all the criteria for evaluating theoretical hypotheses about unobservables, the ability of a hypothesis to explain, successfully predict, and/or be supported by a variety of classes of empirical facts— especially facts that played no role in the initial formulation of the hypothesis—was considered to be the highest criterion of validity. Support from different classes of facts was thought to give rise to a no-coincidence argument for the truth of the hypothesis; namely that it would be an improbable coincidence for a hypothesis (usually about unobservables) to be able to accommodate a variety of (observable) facts and yet for it to be false. This criterion is found more explicitly in William Whewell's (1840b; 1847; 1858) notion of the Consilience of Inductions, but it can also be encountered in the writings of many other nineteenth century philosophers such as John Herschel (1830), William Stanley Jevons (1874), and Charles Sanders Peirce (1878, c. 1905). This paper has two main aims. First, it looks at the method of the hypothesis in the thought of Whewell, J. S. Mill, Herschel, Jevons, and Peirce. It focuses especially on the reasons they gave for the epistemic force attributed to the criterion of consilience, i.e., on their response to the question: why the ability of a hypothesis to explain different classes of facts should be considered (or should not, in Mill's case) as an argument for its truth? Second, it uses the conclusions of the first part to elucidate some relatively recent philosophical discussions on scientific methodology. More specifically, it compares the nineteenth century criterion of consilience with the epistemic strategy of multiple determination—i.e., the epistemic strategy of using multiple, independent experimental procedures to establish the same result—as the latter emerged in the experimental investigations of unobservable atoms and molecules at the turn of the twentieth century. In the literature on scientific methodology, consilience and multiple determination are often considered to be instances of the one and same strategy. Although the multiple determination strategy also gives rise to a no-coincidence argument like the one we find in the nineteenth century criterion of consilience, the two differ with respect to their structure, epistemic role, and epistemic force.

Cassirer's Conception of Hypothesis and the Origin of Special Relativity

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According to Cassirer, the origin of a theoretical hypothesis in physics is almost always due to a conflict in the experimental results or between physical principles. The dialectic between (1) the extension of Galilei's relativity principle to electromagnetic phenomena and (2) the independence of the velocity of light from the motion of the source emerging from Maxwell's equation was a case in question. For Cassirer, Einstein's solution to the problem was transforming it into a postulate. The principle of invariance — in physics objectivity is invariance from particular descriptions — was too fundamental to be dispensed with and had to be valid for all inertially moving frames. For this reason, Einstein began his 1905 paper by discussing an asymmetry in the electrodynamical phenomena that had to be removed. Analogously, the stress on invariance principles on which the new theory was grounded responded very well to Cassirer's interpretation of the history of physics regarded as a transition from the idea that physical hypotheses have an ontological weight (for instance, qua pictorial representations) to the idea that they have the logical function to constitute the new physical theory. A hypothesis has an ontological weight if it is thought to instantiate real physical properties e.g., the ether as a substantial entity carrying properties typical of perfect fluids and elastic bodies. On the contrary, what he calls "the logical function" of a hypothesis is carried out by mathematical expressions relating the main concepts introduced by an hypothesis. In our case, the ether reduces to the expression of mathematical relations between magnitudes that can be measured through experiments (Cassirer [1]162f) Cassirer argued that this transition was realized by Einstein's rejection of the ontological hypothesis that the notion of absolute rest could correspond to real properties of either mechanics or electrodynamics and formulated the logical hypothesis that "the same electrodynamic and optical laws hold for all systems of coordinates of which the mechanics equations hold" [1], 371. The two conflicting hypotheses that Einstein transformed into postulates were logical and corresponded to the two requirements that the new theory had to meet to satisfy both (1) and (2) above what we now know as the two postulates of special relativity. The solution of the contradiction between (1) and (2) was achieved neither by an induction nor a deduction from data but implied a complete restructuring of the foundations of the theory suggested both by the "logical" interpretation of Einstein's hypotheses and by the importance of symmetry principles that according to Cassirer played a fundamental role in the constitution of a physical theory.

Hypothesis and Uncertainty in the Climate Science

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The climate change processes, which are rooted in time at the beginning of the industrial revolution, affect natural and human systems and are considered one of the main global problems that are challenging present and next generations [GEO6]. As a complex problem, climate change raises many methodological, epistemological, and ethical questions under the umbrella of the philosophy of climate science as the interdisciplinary research field. A hypothesis is an important tool for predicting the future, diminishing harms, and constructing scenarios of the adaptability of human socio-economic systems. This assumes the identification of causal relationships between certain actions or events and their environmental and social consequences; the discernment of the main factors resulting in climate change; establishing the connection between harms and behavior of certain actors who should bear the main responsibility for climate change [Page]. The difficulties in the development of hypotheses about the climate change impacts lie in the uncertainty that scholars deal with. Uncertainty is considered a complex phenomenon that has both quantitative and qualitative dimensions. The uncertainty is growing due to a rather big distance between causes and consequences in space and time intervals, and because of inertia of decision-making and implementation. Uncertainty is defined not only by the lack and contradiction of data/facts, but also by the political attitudes, social/economic interests, threats, values, educational standards, and behavior or consumption patterns. The success of the implementation of knowledge of climate science, development of hypotheses, and scenario building often lies outside of the scientific area and depends on politics, economy, low, public priorities and expectations, trust, etc. At the same time measures on environmental and social planning fail due to unpredictable triggering events like natural cataclysms, wars, and other social conflicts. The goal of the presentation is to outline and discuss the approaches to working (workable) hypotheses about the long-term trends and consequences of climate change to fill in gaps in data, knowledge, and arguments and to encourage the policy-makers and other social actors to act.

Causality and Conditionalization

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It is argued that in the absence of causal hypotheses Conditionalization makes little sense. This claim is illustrated with an analysis of the Car-Ride Paradox. The paradox shows that in some situations Bayesian probability estimates in the context of inquiry may seem absurd even though mathematically they are perfectly convincing. In other circumstances, however, the same estimates are indubitable. In appears that what makes the difference is the relevance of evidence one conditionalizes on. The relevance, in turn, depends on the presupposed causal mechanisms of the process in question, rather than statistical correlations. The analysis on offer supports the explanationist approach against the Bayesian and the compatibilist. On the other hand, it does not rebut Conditionalization altogether. Rather, it points to severe limitations of the method that reduce its applications to predictions and statistical hypotheses, in contrast to explanatory hypotheses.

The Proposals of Symmetry as Hypotheses in the Philosophy of Physics of Albert Einstein

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In my presentation I wish to explore the methodological aspect of symmetries in the formulation of both special and general theory of relativity of Albert Einstein. These are the Lorentz group and the group of diffeomorphisms acting on a spacetime manifold, respectively. It is now affirmed that in his theoretical considerations Einstein has reversed the trend of how symmetries are understood: from the consequences of the previously established laws of physics to hypotheses from which the laws of physics are derived and subjected to experimental verification. This trend continued in the imposition of the Lorentz symmetries in the Schrödinger equation leading to the formulation of the Dirac equation and the prediviton of antiparticles. In order to show the significance of symmetries in formulating a scientific hypothesis I will refer to the relation of *duality* between symmetry and invariance according to which the lesser the symmetry (more precisely: the smaller the symmetry group), the more invariants of the group and the richer the structure to which the group corresponds. Also, Joe Rosen's understanding of symmetry as *immunity to change* will be helpful in this regard. Consequently, proposing a correct symmetry group as a scientific hypothesis makes the theory in hand correlate with a structural element of the physical reality the theory prurports to describe. This remains in agreement not only with the contemporary ontological standpoint that these are the structures and not the objects that underpin the fundamental level of physical reality but that these structures reveal great level of specificity and sophistication.

Duogenism: An Example Systemic Way to Reconcile Faith, Reason, and Science

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We introduce Duogenism: a concept of a philosophical system originating from observations of an overlap of magisteria offered by natural sciences and religions. Examples of such an overlap clearly serve as example cases invalidating the NOn Overlapping MAgisteria (NOMA) principle and indicate a need for a new philosophical approach to reorganize cognitive closure in worldviews which have included NOMA so far. The concept of Duogenism has been developed to serve as an example of an intellectual, self-consistent, and systemic way to handle the seeming "issues" in thinking about faith, reason, and science. If such a way can be demonstrated in a convincing way, it would automatically help in building worldviews free of mythological (untrue!) contradictions between the achievements of natural sciences and religious thinking, thus offering a chance for bringing back the latter on an equal foot with the other essential elements that build holistic concepts of reality. In fact, the wide formulation of our system might make it the first representative of a new family of universal and self-consistent concepts of holistic worldviews which are compatible with the mathematical descriptions of reality offered by natural sciences, and which also contain a naturally inherent room for religious or metaphysical thinking to explain that part of reality which presently lies beyond the reach of natural sciences. Since such a family merges the two "traditionally" separated realities: material and spiritual ones, into just one "smooth" universum, we propose to dub this family Duogenism, for its dualism and to stress that the two intellectual origins are proposed to be unified under one self-consistent thinking system. Such a name would also refer to the tension between the two big concepts of human origin: Monogenism and Polygenism — Duogenism already by its name promises some chance for reconciliation here. Despite being primarily oriented on logical integrity, Duogenism might provide a very practical insight into how the world truly works, i.e. it might trigger "standard" scientific discoveries. Here we propose a duogenism (the first member of the Duogenism family) based in its physical part on the concept of everything adopted from the Wolfram Physics Project, and the spiritual part is compatible with the teaching of the Catholic Church taken as an input which is confronted with the experiences and knowledge provided by natural sciences, where such a confrontation requires a deep thought on possible physical implementations of reality which do not violate logic. The resultant implications reveal both apologetic and epistemic aspects of the proposed system, the latter including hypothesizing on a fundamental level of physics.

Real Advances in Experimental Physics Need Bold Working Hypothesis

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Physics is the science that combines the theory and "experiment, as the ultimate check of the theory" (Albert Einstein). Experimentally proved ideas from physics (and astronomy) like the heliocentric model, the theory of relativity or the principle of indetermination led to fundamental changes not only in philosophy, but broader — into man-on-the-street perception of the world. But philosophy would tend to proceed beyond — proposing specific meanings to equations of physics. So, the quantum indetermination principle, in origin experimentally motivated (Heisenberg), is used to motivate metaphysic ideas, like God acting in the indetermination time gaps. As we argued such consequences do not find the consensus among physicists. An equilibrium between "free-lance" speculations and "hard" physical data must be searched: research hypothesis require experimental validations. We give three, personal examples.

1. The first comes from atomic physics. Modern interpretations teach that we can not know "exact" dimensions of the atom: electrons form a kind of a cloud. How can we measure it? By so-called cross section: sending a beam of particles much smaller than an atom. But again, the "experts" say that the cross sections is governed by quantum mechanics. Young researchers do not agree. The path was long and included many years, different methods and laboratories scattered over the word. The result came unexpected: not electrons but anti-electrons (positrons), not at high energies but at low, and not in a single point but over a wide range. Positrons do really measure dimensions of atoms and molecules. But surprisingly, these "hard-sphere" diameters (using the term from classical physics) find a nice interpretation by quantum physics.

2. The second example comes from solid state physics. Semiconductor diodes may emit light: all semiconductors but the most common (and cheap) i.e. silicon. This is due to a specific configuration of conduction and valence bands. Again, young researchers do not believe. It appeared that if nano-clusters in SiO_x were induced by thermal treatment, such a sample emited light: the solutions of quantum theory need different border conditions.

3. The third example involves chemistry. The textbook structure of the acetic acid shows two oxygens in the carboxylic group non equivalent. Again, it seems that the hydrogen (or better: a proton) travels between two oxygens, in a resonant-like way. This third hypothesis still awaits further experimental validation.

The basis of new discoveries are always bold hypothesis, and the ability of the researcher not to oversee the revolutionary answers of the Nature.

Similarities and Differences Between Bilikiewicz's Concept of the Spirit of Time and Kuhnian Paradigm

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In 1932, Tadeusz Bilikiewicz published a work devoted to a rather poorly developed part of the history of medicine, namely the beginnings of modern embryology. In addition to presenting current factual knowledge in this field, this forgotten book attempts to reconstruct the sets of patterns valid in the eras of Baroque and Rococo, so that the 'long lines of development' that characterized them can be identified. According to Bilikiewicz, such an identification enables the practice of history, which is not merely a collection of facts, but gives a 'cognitive orientation towards reality' (and thus allows one to explain and predict). Bilikiewicz—following Wölfflin and Joël—calls these patterns the 'spirit of the time' (Zeitgeist). In science, the spirit of the time appropriate to a given historical period determines scientific objectives and the range of problems to be addressed in science, defines the methods by which their solutions can be obtained, and influences both the choice of empirical data and their interpretation; this is also the case in embryology. Each Zeitgeist is a theoretical construct—a hypothesis by which the conduct of scholars in a given period can be assessed as rational. Against such a background, Bilikiewicz outlines his sociology of scientific knowledge. Now, the Zeitgeist understood in this way bears a striking resemblance to Kuhn's paradigm in many respects and at times it is striking. The aim of this paper is two-fold. First, it is to show what these similarities are and what the limitations are when comparing these concepts. Second, it is to illustrate the use of speculative hypotheses in the pioneering stage of scientific research using the example of embryology.

Understanding Phenomena With Machine Learning Models

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The deployment of Machine Learning (ML) models in scientific research is showing that they can make accurate predictions in domains where traditional models or simulations have failed to do so. However, science is not just about prediction, it is also about understanding. This talk addresses the following questions: can ML models provide understanding of phenomena? If so, how? And, more importantly, what is the nature and reach of that understanding? I argue that the answers to these questions depend on whether these models are interpretable or opaque. Here, I follow the distinction made and defended by Rudin et al. Namely, while an interpretable ML model "obeys a domain-specific set of constraints to allow it to be more easily understood by humans," an opaque ML model is a "formula that is either too complicated for any human to understand, or proprietary". I show that this distinction has implications not only for understanding the model itself, as it directly follows from Rudin's definitions, but for the understanding of its target phenomenon. To illustrate my point, I focus on Deep Neural Networks (DNNs) —the quintessential black boxes— and compare them with traditional models. In addition to opaque DNNs, I consider two kinds of interpretable ML models: 'disentangled' DNNs and approaches that combine Deep Learning with Symbolic Regression. Through these comparisons, I show that the explanatory work of these models is done by the hypotheses they can provide (in the case of interpretable ML models) or by the hypotheses they are in part based on (in the case of traditional models). To make this clearer, I draw on Bunge's classification of scientific hypotheses based on their explanatory depth. Namely, programmatic, black box, grey box, and translucent box hypotheses. Programmatic hypotheses have the form 'variable y depends on variable x,' and invite research projects of the form 'find f in y=f(x)'. Which is precisely what ML is about —learning functions from data sets. However, these functions can be "too complicated for any human to understand." Thus, I argue that while interpretable DNNs can provide black box hypotheses (i.e., those that answer questions of the "what is it?" type), opaque DNNs cannot do so. To avoid extra confusion due to the already overused black box terminology, I call these hypotheses 'f-hypotheses,' since they are or refer to functions. These f-hypotheses differ from the built-in grey and translucent box hypotheses (i.e., those that answer questions of the "how does it work?" type) of semi-phenomenological and mechanistic models, respectively. Nonetheless, I show how interpretable DNNs can aid both semi-phenomenological and mechanistic explanations. In addition, I discuss to what extent one can extract f-hypotheses from opaque DNNs with post hoc XAI methods.

Will the Success of Causal Discovery Methods Herald the End of Hypothetical Thinking?

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Causal discovery methods (CDMs) aim to generate a causal model from (observational) data generated by the target causal entity/process. They do that by searching through the problem space of all possible causal models. Otherwise, hypothetical thinking generates particularly plausible "what if" causal models, which must be verified experimentally. The radical empirical view states that — amid CDMs' success — there will be no need to generate plausible hypotheses because the answer lies in the data itself. Against this view, I argue why scientists should focus primarily on hypothesis generation in inquiry with CDMs. First of all, we have hypotheses at different interactive levels. For example, Copernicus' heliocentric hypothesis expanded the problem space for Kepler's working hypothesis: there is discoverable elegant order to the celestial bodies' motion. Next, the elliptical orbits hypothesis narrowed a problem space such that he could find his hypothetical laws consistent with the better data from Brahe. I propose to frame such phenomenons as (open) creative problem solving, specifically as meta-problem spaces formalised by metalanguage, rather than as (closed) Bayesian inference, specifically as hierarchical Bayes models, where we inductively update many problem spaces levels simultaneously. The latter is good, but not enough — especially when explaining breakthrough discoveries — and its proponents reported the need for integration with the first. A radical empirical view of CDMs is fundamentally and practically untenable. Defining a problem space is a hypothesis, and even if true, it's so large and complex that the search is virtually impossible. Also, CDMs themselves imply a hypothesis about the relationship between causality and probability, so they have to be experimentally tested. I argue that the success of CDMs lies in the interaction between hypothesis-creating scientists and data-driven CDMs. Scientists can help CDMs: hypotheses about aggregating low-level variables into higher-level ones reduce computational requirements, hypotheses about individual causal relations reduce the problem space etc. CDMs help scientists, i.a by proposing pivotal relations to be experimentally stated for identifying the unique causal model, indicating which variables have been poorly aggregated, or where explanans or explanandum is fallacious.

Today, amid the integration of vast sets of experimental data and the rapid development of CDMs, the possibility emerges for the systematic search for causal models. In such a world, the generation of new and valuable hypotheses should be the main job of scientists.

What Makes Hypotheses Accurate? An Empirical Study

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In this talk, we report the hypotheses, methods and results of an empirical study of how researchers study the accuracy of hypotheses. Our study was provoked by (Mizrahi 2021), who uses the results of plain-text searches over scientific publications to argue that appeals to standard theoretical virtues are surprisingly uncommon in scientific literature, with accuracy and fruitfulness being invoked especially rarely. Although we support Mizrahi's general goal of gaining empirical insight into scientific practice through data science, we take issue with the specific methodology he employs. Our aim is two-fold. First, we show that Mizrahi's study relies on false assumptions regarding what the standard theoretical virtues are, how they are expressed linguistically and what objects are assessed in terms of those virtues. Second, we describe a method of studying theoretical virtues with the tools of corpus linguistics so as to replace Mizrahi's assumptions by data-driven hypotheses. The idea is that we should first discover what kind of virtue-related expressions scientists actually use and then exploit that information to find out what theoretical virtues there are and what kind of objects can possess them. In general, our study shows that scientists actually speak of accuracy and inaccuracy of hypotheses but most frequently in terms of truth and falsity. We also point out that a major problem in empirical research on scientific writing is how to operationalize appeals to epistemological features one aims to study. Such operationalizations should include clearcut guidelines for human annotators, who are indispensable in analyzing textual data. The general lesson is that data-driven metascience can provide significant lessons for epistemology, but as all science, it must be empirically sound.

Normative Factors in Hypothesis Formation and Selection

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There is a growing consensus that the notion of value-free science is misplaced (Douglas 2015). Instead philosophers and scientists should focus their attention on related questions, including: how to limit inappropriate influence of values on scientific inquiry, how to facilitate explicit statement and identification of relevant values, and how to proactively incorporate values in order to improve scientific practice. As regards the third question, for instance, one emphasis in the literature has been on the importance of considering possible societal implications of scientific research (Kitcher 2011; Douglas 2014). An issue that is neglected by this literature, and more broadly, is the role of normative considerations in relation to research hypotheses themselves — rather than the subsequent scientific work or use made of scientific findings. The present paper seeks to remedy that omission through an analysis of hypothesis formation and selection. Normative considerations in this context are defined to include values, but could themselves be subsumed within a larger category of strictly non-epistemic factors. There is an ongoing debate about the merits of non-epistemic factors in scientific inquiry (Elliott and McKaughan 2014; DiMarco and Khalifa 2022). Nevertheless, the discussion of hypothesis formation considers how strictly non-epistemic factors influence hypothesis formation and what the implications might be, if any, for scientific progress. The discussion of hypothesis selection is more nuanced. We sketch a model in which there exists a set of hypotheses pertaining to a given research question and a researcher selects a hypothesis from the set for the purposes of theoretical development or empirical testing. Non-epistemic factors contribute to how the researcher selects the hypothesis. The implications for progress depend on the distribution of such factors within the scientific inquiry. Furthermore, we argue that the ontological structure in which inquiry is conducted also determines the degree to which the implicit incorporation of non-epistemic values can affect scientific progress.

Émilie du Châtelet's Hypotheses in Action: How Motion Works

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Although the eighteenth century has been considered a period in which Newtonianism reigned —something that is not entirely accurate—, the question of scientific method is still pertinent. If we analyse the scientific situation at the time, we will find that the Cartesians used too many hypotheses and the Newtonians none or few. However, not every natural philosopher fits in these two labels. Among the ones who do not, we find Émilie du Châtelet, a philosopher and scientist who, in her Institutions de Physique, shows us a new method of scientific practice. Châtelet uses a combined methodology. In her method, we find the first principles of knowledge introduced by Leibniz, i.e. the principle of sufficient reason and the principle of non-contradiction, the principle of continuity and the principle of the identity of indiscernibles. Using the first principles as a fundamental part of his methodology, Châtelet concludes that hypotheses are useful, as they can guide our thinking towards the truth. In this sense, she rejects both the idea that hypotheses only create fictions, as Newtonians would say, and the idea that hypotheses do not lead to any safe path. In my talk, I want to show the way by which Châtelet arrives to the use of hypothesis through the first principles. I will also show how these principles are needed to create safe hypothesis which guide our thinking to the truth. Furthermore, the principles are also needed to avoid obstacles when we want to create a good hypothesis, so they help us to distinguish a good hypothesis from a bad one. In order to frame my ideas, I will show how these hypotheses work when applied to movement. Through the analysis of Châtelet's work regarding hypotheses and motion, I will show that hypotheses are an integral part of the 'making of' science, and not a mere residual device that remains outside the theoretical prediction of phenomena.

From Hypotheses to Systemacity and Back

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There are, at least, two perspectives on the functioning of the hypotheses in the scientific research. One of them concerns the confronting hypotheses with evidence, for or against them (a.k.a hypothesis testing); second one considers hypotheses as part of theoretical practices, as they are formed and changed under theory development (a.k.a. hypothesis construction). Here, hypotheses play important role in the sophisticated, nuanced and systematic theoretical practice. Even this may sound trivial, it is not, at least not for everyone. And this second perspective, though no less important, is often neglected.

The disaster of neglecting this theory-related face of hypotheses is currently reflected in the situation of psychology, experiencing of newer and newer crises. This strange situation has been recently noticed (Scheel et al. 2020). This fact and bias of the psychology toward to hypotheses testing practice — makes it especially well-suited to depict the importance to the theoretical practice of hypothesis formation.

Looking the view from within, I will start here from remarks on almost forgotten Mook's paper (1983) on the neglected — not related to generalizability - role of hypotheses in theory testing practice and present some voices for theory practice development in psychology (Kukla 1989). Then I move to recent works on role of story, or narrative (where is formed, could be seen as mark to the systematicity) in theory and scientific pursuit in general development. I want to propose a more explicit role that hypotheses play in systematicity of theory (development) and vice versa.

To enforce the main point of my talk, I study two examples. The first one (negative), from the current, ongoing research on body representations, where the overwhelming load of empirical results is presented without more substantial theoretical work and in effect makes it hard (or even impossible) to track developments and find a coherent thread in it. Second one (positive), from the work on maternal bound in the attachment theory (see: Cassidy, Shaver 2002), where more advanced theorizing gives one the opportunity to track and notice the gain (evidenced e.g. by recent work about role of the interception plays in attachment).

Wrapping up, I will argue, by showing on the examples from psychological research, that hypotheses as part of theoretical practice are the feature of scientific practice in general.

Bridging the Gap Between Philosophical Controversies and Scientific Contributions — Perović's Account of the Inductive-Hypothetical Method

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Philosophers of science often have the difficult task of reconciling the outstanding experimental contributions of scientists on the one hand and their controversial philosophical views on the other (e.g., Bacon, Boyle, Einstein, Bohr). *In From Data to Quanta: Niels Bohr's Vision of Physics*, Perović (2021) attempts to unravel the puzzle of the great Niels Bohr's controversy. He adopts a cross-disciplinary approach characterized by main inductive hypotheses (which he calls "master" hypotheses) in analyzing the new experimental techniques that emerged in the 1930s. In a philosophical sense, Perović depicts the relationship between the theory and experiments of the inductive-hypothetical approach that shaped Bohr's practice. Thus, he distinguishes the phases and levels of hypotheses with different degrees of generalization, from the basic experimentalism, which relies on everyday language to describe classical concepts of physics, to the master hypothesis, which is non-classical in all respects. Suppose we start not from metaphysics and epistemology but with a historically oriented analysis of the methodology of a particular scientist. In that case, we can much better understand his contributions and deconstruct the controversies that accompany his philosophical excursions. The primary goal of the arguments we rely on is to trace the structure of the scientific method through numerous historical studies. The secondary goal is to present a scientific theory's epistemological and metaphysical aspects. The methodological understanding of specific scientific contributions through a historically motivated philosophical analysis of the constant and rigorous oscillation between theories and experiments allows us to understand the scientific community's broader context and distinguish between scientific practice and metaphysically and mathematically oriented concepts. The central argument of our work is the "bottom-up" foundation of the inductive process in experiments. Induction, moving "bottom-up," is deeply rooted in a long experimental tradition since Francis Bacon and represents the core of a complex human activity presumed under the name "scientific method." Influential philosophers of science such as Lakatos, Kuhn, and Feyerabend often neglect the role of experiments, creating interpretive misunderstandings. Perović's particulate-inductive model arises from studying the history of quantum mechanics and particle physics. We want to generalize this approach to explore the different stages of theory development, each characterized by a substantially different approach to phenomena, particularly concerning the relationship between theory, experiments, and facts. Therefore, we want to clarify why experiments play a central role in generating hypotheses at all levels of theory development. This paper aims to explain, from an experimental perspective, how hypotheses are formed and to answer the question of whether facts or rules guide the inference process. In analyzing the structure of the process that has produced the significant achievements of numerous scientists, we will explain how experimental hypotheses and the experimental context pave the central path while other theoretical and formal metaphysical aspects are secondary. Through a focused foundation of an inductive-hypothetical understanding of the methodology and scientific practice, we will attempt to extend Perović's deconstruction of the Bohr's Puzzle to a more general scenery of the philosophy of science.

Kant on “Saving” Hypotheses in Science

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Kant defines hypotheses as “the opinion of the truth of a ground from the sufficiency of said ground for its consequences”, and insists on the indispensability of hypotheses in empirical sciences. Good hypotheses are not just the starting point for inquiring if something is the case, eventually arriving at the knowledge of it; the entire method of inquiring — from where to begin in collecting empirical data and constructing experiments — depends on what is assumed as a hypothesis. And yet, hypotheses may be confused with other forms of assuming something without investigation. Accordingly, Kant specifies that when we form hypotheses we should judge provisionally, but avoid prejudices; we should assume something we can simply conceive, but without fantasizing. If the moment of hypothesis formation is so crucial, and yet so endangered by confusing hypotheses with competitors, such as prejudices and fancies, can we distinguish between hypotheses, prejudices, and fancies at the formation phase? The short answer to this question is that there is a method of making hypotheses that prevents prejudices and fancies. The aim of the talk is to argue that Kant’s program in the Critique of Pure Reason also intends to invest hypotheses in science of epistemic values after their misuses in metaphysics. To this end, the talk explores what hypotheses for Kant are and how they fit into Kant’s modes of holding-tobe-true. This systematic reconstruction sheds light on Kant’s criteria of making hypotheses and explains why hypotheses differ from competitors like fancies and prejudices already at their formation phase. Insisting on a distinction between hypotheses, fancies, and prejudices at the formation phase explains why Kant can: accept hypotheses in science as a doxastic attitude, remaining faithful to the Newtonian maxim “I do not feign hypotheses”, while differentiating himself from the Leibnizian-Wolffian tradition; reassess the control phase: control simply augments the perfection of hypotheses, eventually determining is truth value — it does not distinguish hypotheses from other competitors. The certainty of a hypothesis varies with control: the more the hypothesis acquires in perfection, the more it tends to be transformed from provisional into a determining judgment, although the inductive basis on which it builds never provides apodictic certainty for the judgment that expresses it.

Is Scientific Knowledge Factive?

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The dominant position in today's epistemology is that knowledge is factive in a conceptual, linguistic, and normative sense. That means that it is impossible to know what is not true, that knowledge presupposes truth, and ultimately that truth is the norm for knowledge. The thesis about factivity of knowledge is related to the involuntarily of knowledge, which means that knowledge is not the result of someone's decision: I may decide that I know, but it can turn out to be false, or I may decide that I do not know what can turn out to be true. Such a position seems to be in contradiction with the notion of scientific knowledge, which is based mainly on hypotheses and methods of their justification. A question arises about whether the scientific knowledge is factive. Adam Grobler has presented several objections against the factivity in scientific knowledge. There are cases, as he says, where something was once considered knowledge and is no longer today — an example would be replacing the geocentric theory with the heliocentric one. We can also talk about better scientific knowledge and worse. Moreover, scientific knowledge is built upon presuppositions, including idealization assumptions, which define the field for deciding between candidatures for knowledge while remaining unjustified. In his view, propositions that make up scientific knowledge are the ones that can survive the influx of new evidence until the presuppositions are rejected, not the true ones. We will argue against Grobler's objections and defend the view that scientific knowledge — as the kind of propositional knowledge — is factive.

Modelling in Science and Surrogate Reasoning: For an Interactive and Dynamic Perspective of the Generation of Hypotheses in the Practice of Modelling in Science

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The aim of our talk is to defend the idea that to generate a hypothesis in the practice of modelling is to make an agreement that justifies that the conclusions obtained on the Model (M) gain the status of hypothesis in its Target System (TS). In such cases, according to Swoyer (1991, p. 449), “we use one sort of thing as a surrogate in our thinking about another, and so I shall call this surrogative reasonin”. So, according to our point of view, this generation of hypotheses as surrogative reasoning should not be understood statically as the conclusion of a reasoning in M which is then considered as a hypothesis in TS. On the contrary, we will argue that hypothesis generation should be understood dynamically as an inferential agreement generated between M and TS. Concretely, our idea is that to generate a hypothesis is to establish a conditional agreement that justifies that what is proved in M is considered a hypothesis in TS. Therefore, we will show, first, that to generate a hypothesis is to establish an agreement between two pieces of evidence. And, secondly, it is questioned whether the ultimate foundation of hypothesis generation in modelling practice is the notion of representation.

The Atomic Hypothesis and its Role in Field Theories

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The aim of this paper is to discuss the relevance of the Atomic Hypothesis in the context of field theories of matter and radiation, such as classical electromagnetism and Quantum Field Theory (QFT). The Atomic Hypothesis has had an important heuristic role in all the history of science. Since the atomistic philosophy of Leucippus and Democritus, the idea that our world is ultimately made up of small and discrete particles has guided the work of many scientists. In particular, several corpuscolar theories has emerged in the XVII and XVII centuries, and this has led to the birth of the modern chemistry and its theory of chemical elements. However, the first classical field theories — such as electromagnetism — has changed the perspective on the structure of the world. Since the formulation of electromagnetism, the notion of field seems to have substituted that of particle in the search for the ultimate ontology of physical reality. Moreover, the notion of particle faces several conceptual problems in the context of QFT, due to some no-go theorems and technical results. As such, it seems that the new fundamental hypothesis behind contemporary physics is that fields are the fundamental entities, while particles are only an approximation. Nonetheless, my claim is that the notion of atom and that of particle have played and still play an important heuristic guiding role in the formulation of the field theories of matter and radiation. For example, the notion of charged particle was fundamental in Faraday's definition of the line of forces of the electric field and to the first definition of the electric field itself. In QFT, the notion of particle was important in the so-called second quantization, which led to Dirac's formulation of Quantum Electrodynamics. The particle notion was also fundamental in the formalization of the interaction picture via Feynman's diagrams — scattering theory is represented in particle terms as well. I will then show how the Atomic Hypothesis still plays a fundamental heuristic and methodological role in the reasoning of scientists, even in the context of the field theories of matter and radiation. This is an epistemological claim, since my aim is not to defend the relevance of the Atomic Hypothesis for what concerns the ontology of the physical world, but rather its importance for the formulation of our theories.

Hooke's Attempt to Prove the Copernican Hypothesis

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In 1674 Robert Hooke (1635-1703) published An attempt to prove the motion of the Earth from Observations, a text that seeks to explain the Copernican hypothesis and to establish the principles of a Theory of Gravitation. The content of this Attempt would have been presented for the first time in 1665 in the public meetings held at Gresham College during the Physico-Mechanical Lecture. According to John Cutler, Hooke to wanted to publish his observations only when he had replicated the experiments. However, he was unable to replicate them due to bad weather and health related reasons. Hooke thus decided to publish them in 1674. In this text, the author summarizes one of the most important debates in science at that time: the emergence of the Copernican hypothesis and its dispute with Tycho Brahe's model. As Hooke notes, the teaching of the Tychonian and Ptolemaic systems was still prevalent. Tycho Brahe reportedly observed a new star on the 11th of November 1572 in the constellation Cassiopeia. Due to this observation, Tycho had already set the Aristotelian theory aside, as this new star was proof that there was change in the celestial world. However, Tycho Brahe did not adopt Copernicus' system. He rather created a mixed system between Ptolemy's geocentrism and Copernicus' heliocentrism. Tycho Brahe's hypothesis was invalid for Hooke, but he also thought that Copernicus' argument, which places harmony at the center of the justification of Heliocentrism would not be sufficient to validate his system. Arguments are not enough. Something more was needed: experimental proof. Hooke also criticizes the fact that Kepler, Riccioli and Tycho drew their conclusions from observations made with the naked eye. Copernicus' hypothesis can be better supported with the help of instruments which help us improve our senses. Hooke proposed to use the zenith telecope he had built to measure the parallax of a fixed star to prove that the Earth moves. He reportedly made observations between July and October 1669, focusing on the fixed star in the Dragon constellation. Despite his efforts, these observations were not enough to measure parallax. This measurement was only possible in 1830. However, this text introduced a new way to prove the Copernican hypothesis: by proving that the gravitational force exists and how it works.

Hypothesis, Robustness, and Scientific Practice

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Hypothetical thinking is an indicator of a scientific realist mindset in the practice of science. It acknowledges the richness of reality and ensures that such is accounted for with robustness. Wimsatt (2007) establishes robustness as a criterion for "something real or trustworthy." Things are robust if they are accessible via multiple independent means. Multiple independent means of access may range from direct experimental manipulations to mathematical derivations. Hypothetical thinking brings to light the robustness of scientific realism which asserts that "most of the essential unobservables of well-established current scientific theories exist mindindependently." Michela Massimi, 2017 recipient of the Wilkins-Bernal-Medawar Award from UK's Royal Society, expresses, "…a realist viewpoint can include our ability to carve out the space of what might be objectively possible in nature, rather than in terms of mapping onto some actual states of affairs." Hypothesis must lead to further investigation for it to be verified and falsified. It carves the space of what might be possible. Earlier iterations of a hypothesis may hold the space for 'saving appearances'. Ultimately, however, the hypothesis must jumpstart the unearthing of the underlying causal mechanism. Results from ensuing investigation lead to credible theory. Such theory does not settle for heuristic devices that save appearances, the instrumentalist mindset, but accommodates unobservable realities that cause the phenomenon. The traditional take on hypothesis is that it must lead to testable results. It is thus that the multiverse theory elicits considerable resistance because it does not lead to feasible and realistic experiments. Waters (2017) advises that "scientific metaphysicians interested in complex reality should focus on scientific knowledge (including theoretical knowledge) in the context of scientific practices (broadly speaking), not in an abstract context in which theories can be viewed separately from material practices designed to advance investigative and manipulative goals." Looking at scientific practice makes the case for robustness as a parameter for what is real and trustworthy. Robustness, confirmed through independent means of access and tests, rests on the prioritization of scientific practices rather than on a global theory. For hypothesis to transition to well-established theory there has to be the consideration of scientific practices that facilitate robustness. Standard Anglophone philosophical analyses of science have been unduly limited by the common habit of viewing science as a body of propositions, focusing on the truth-value of those propositions and the logical relationships between them. Theory and world build on each other for a more refined theory and a better understanding of the world. Theory supposedly informs practice, the experimentation and other related epistemic activities and systems of practice. Practice refines theory just as theory informs practice. The transition of hypothesis to wellestablished theory is necessary for the effective study of modern-day science because science has to be robust. Robustness is exemplified in the well-established theory that necessarily incorporates practices.

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