De Regt, Henk W, *Understanding Scientific Understanding* (NY: Oxford University Press, 2017, 320 pp.)

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1. Introduction

It is only recently that "understanding" has become a topic of debate within the field of the philosophy of science. The reason for this "delay" has been the philosophers' focus on "scientific explanation" as the proper notion for analysis, a preference that can be traced back to Carl Hempel's and Paul Oppenheim's 1948 "Studies in the Logic of Scientific Explanation" (repr. in Hempel, 1965). This pioneering paper not only marked the beginning of extensive discussion of explanation in science, but it also dismissed "understanding" as an overly psychologistic and pragmatic notion, and thus steered philosophical attention away from it. Admittedly, "scientific understanding" has not been neglected completely – first it was Michael Scriven's "Explanations, Predictions and Laws" (1962) that brought the notion to the fore. Later, in his 1974 "Explanation and Scientific Understanding" Michael Friedman argued that philosophical accounts of explanation should clarify how such explanation produces understanding. Since then philosophers have often pointed out the understanding-providing power of their preferred models of explanation. However, apart from these few exceptions, as well as Achinstein's *The Nature of Explanation* (1983), philosophical attention has remained focused on "explanation" and detailed analysis of "understanding" has been avoided.

It was in the field of epistemology with the work of Linda Zagzebski (1996), Catherine Elgin (1996), and Jonathan Kvanvig (2003) that a discussion was provoked about the difference between epistemology's traditional subject matter of knowledge and understanding; as a result, the position of the latter was established as a cognitive achievement worthy of philosophical examination. As far as the philosophy of science is concerned Henk de Regt's work has been among the main factors for reintroducing "understanding" and its relations with "explanation" as one of the issues of discussion within the field. Thus, in the last ten years there has been an increase in related research, with an attendant increase in the number of publications on this topic : *Scientific Understanding: Philosophical Perspectives* (de Regt, Leonelli and Eigner, 2009), *The Nature of Scientific Thinking: On Interpretation, Explanation, and Understanding* (Faye, 2014), *Explaining Understanding: New Perspectives from Epistemology and Philosophy of Science* (Grimm, Baumberger and Ammon, 2017), *Understanding, Explanation, and Scientific Knowledge* (Khalifa, 2017) as well as de Regt's own *Understanding Scientific Understanding* (2017).

2. An HPS approach

The composition of *Understanding Scientific Understanding* – it is divided into two major parts, a theoretical part (chapters 2 to 4) and a historical one (chapters 5 to 7) – reflects its author's ambition: unlike mainstream philosophical discussions of explanatory understanding, which de Regt qualifies as historically uninformed, his inquiry aims to combine successfully systematic philosophical analysis with detailed historical narrative. He explicitly positions his work in the tradition of integrated history and philosophy of science approaches (HPS). However, as de Regt clarifies in the introduction, this structure does not reflect a relation between theory and historical record, in which the latter provides an empirical test for the former. In contrast to this "confrontational model of HPS," de Regt claims to adopt an approach, which, following suggestions by Jutta Schickore (2011) and by Hasok Chang (2012), proceeds upon a close and constant interaction between philosophical concept analysis and historical narrative whereby philosophically clarified notions are used as tools for approaching and interpreting historical data, but also historical data help to further refine and modify the initially articulated notions.

Thus, as de Regt points out, it was a "historiographical puzzle", namely, the controversy at the genesis of quantum mechanics in the 1920s, that inspired his theory of scientific understanding since the mainstream philosophy of science, as he saw it, appeared incapable of providing an adequate account of the research strategies adopted by the opposing parties involved. This case study, as well as another one included in the historical part of *Understanding Scientific Understanding*–the controversy between Maxwell and Boltzmann over the specific heat anomaly–can be traced back to de Regt's Ph.D. thesis "Philosophy and the art of scientific discovery" (1994). Focusing on these two controversies, he thereexplicated the disagreement, as well as the particular solutions scientists espoused, in reference to their philosophical positions. This interpretive move implied the rejection of the traditional distinction between the context of discovery and the context of justification. *Understanding Scientific Understanding* represents the integration of this historical work with de Regt's most recent elaboration of his contextual theory of scientific understanding. This theory was first presented in "Reduction and Understanding" (de Regt and Dieks, 1998) and "Ludwig Boltzmann's Bildtheorie and Scientific Understanding" (de Regt, 1999), then it was more fully developed in "A Contextual Approach to Scientific Understanding" (de Regt and Dieks, 2005), and further refined in "Understanding and Scientific Explanation" (in de Regt, Leonelli and Eigner, 2009).

Completely in the line of the HPS approach, what *Understanding Scientific Understanding* aims at is a theoretical account of scientific understanding that pays due attention to scientists' beliefs and to actual scientific practice. That is why, de Regt argues, it is a contextual theory – one that accounts successfully for historical and disciplinary variation in the standards of explanatory understanding, and yet still specifies some general criteria for achieving scientific understanding whereby the purely local context is transcended. History has shown, the author insists, that the search for universally valid, timeless standards is futile.

3. Understanding Scientific Understanding – the theory

De Regt builds the book's theoretical component by taking three steps. First, he clarifies and rejects the reasons behind what he sees as a neglect of the notion of understanding by philosophers of science (chapter 2). Then he examines accounts of understanding provided by standard models of scientific explanation and argues against the universal validity of any one of them; what is needed, he claims, is an overarching pluralist theory that explains how each of these can provide understanding (chapter 3). Finally, he formulates his own contextual theory of scientific understanding (chapter 4).

3.1 Against the subjective nature of understanding

As mentioned, Oppenheim's and Hempel's work was of huge significance for the subsequent exclusive focus of philosophers of science on the notion of explanation, and thus, it is not simply by chance that de Regt confronts the main charge usually leveled against any attempt for a philosophical account of "scientific understanding", that of pragmatism and subjectivity, as it was articulated by Hempel (1965, 1983).

In accordance with the spirit of logical empiricism which, according to de Regt, remained dominant in the field of scientific explanation in the 1960s and the 1970s, Hempel took "scientific understanding" and "intelligibility" as belonging not to the field of philosophy, but to psychology or the history of science – as scientific laws and theories are objective in the sense that their empirical implications and evidential support are independent of scientists' beliefs and attitudes, the aim of the philosophy of science should also be the objective analysis of scientific statements and their relation to evidence. In contrast, by means of their reference to human subjects, the explainers and the audience receiving the explanation, the notions of intelligibility and understanding are pragmatic and, hence, relative, since something can be intelligible for one audience and unintelligible for another. This equation of the pragmatic with the subjective and the psychological is shared by J. D. Trout (2002, 2007) who draws attention to the psychological biases that may affect the so-called aha-feeling of understanding and that is why, according to him, the feeling of understanding is unreliable when the correctness of an explanation is being evaluated.

De Regt agrees that "understanding" can be used only in reference to human agents – "understanding" is a three-term relation between a phenomenon, an explanation, and the person who uses the explanation in order to attain understanding of the phenomenon. He also distinguishes between the feeling of understanding (FU), object of Trout's criticism, the understanding of a phenomenon (UP), which is usually regarded as the main epistemic aim of science, and the understanding of a theory (UT) equated by him with an agent's ability to use the theory. De Regt is cautious to avoid confusion between UP and UT and he renders "S understands theory T" as "T is intelligible to S", with the "intelligibility" of a theory being an important notion in his theory.

De Regt interprets the position shared by Hempel and Trout as based on the adoption of a strict division between the epistemic and the pragmatic, where the former refers to the beliefs of scientists about the relation between theory and world, whereas the latter refers to their attitude towards the theory itself. This strict division, claims de Regt, presupposes that the epistemic status of a theory depends on a direct evidential relation with phenomena.

Thus, in his refutation of Hempel's influential claim asserting the irrelevance of "understanding" to the philosophy of science, de Regt follows two steps. First, he argues against the above mentioned division by showing that the evidential relation between theory and phenomena is not direct, that is, there is no "objectivity" as independence from scientists' beliefs and attitudes. Second, following Friedman's suggestion that "objective" can be understood as "being constant for a large class of people" he refers to Longino's and Douglas's analyses of the notion of "objectivity" which demonstrate that its being dependent on the beliefs and attitudes of scientists does not make it "subjective" in the sense of varying from one individual to another (Longino, 1990; Douglas, 2009a, 2009b).

The lack of direct evidential relation is clear, according to de Regt, in scientific practice, where skills and scientific models mediate between scientists and phenomena. Skills and models are necessary for the construction of scientific explanations, which de Regt takes to be arguments in the broad sense – answers to the question of why a particular phenomenon occurs, which present a "systematic line of reasoning that connects [them] with other accepted items of knowledge (e.g. theories, background knowledge)"; explanations are not necessarily linguistic, they may take the form of pictorial representations, as well.

Providing as examples Hempel's own deductive model, Wittgenstein's qualification of what it means to understand a mathematical series (Wittgenstein, 1953), as well as Harold Brown's discussion on constructing and evaluating deductive proofs in logic (Brown, 2000), de Regt concludes that these point to the indispensability of skills and tacit knowledge for the construction and evaluation of arguments/explanations. Moreover, these are skills that are learned through practice alone, and are, therefore, contextual. The lack of any direct evidential relation between theory and phenomena is also testified to, according to de Regt, by scientific models. He refers to Nancy Cartwright's "simulacrum account" of explanation (Cartwright, 1983) and to Morgan's and Morrison's notion of the "autonomy" of scientific models (Morgan and Morrison, 1999) and argues that models are derived neither from theory nor from empirical data. Their construction does not follow any algorithms or formal principles, but requires idealizations and approximations which ultimately rely on practical judgment and skills. Thus, de Regt claims, the achievement of a scientific explanation has an inherent pragmatic aspect.

For the clarification of the nature of these skills de Regt uses the notion of theoretical virtue and refers to Thomas Kuhn's list of five theoretical desiderata (Kuhn, 1977), that is, to the qualities of a theory which influence one's choice of theory as values rather than determine it as rules: accuracy, consistency, scope, simplicity and fruitfulness. Skills and theoretical virtues, argues de Regt, are correlated since scientists prefer theories which correspond to the skills they have acquired and improved in training and research; that is why this preference varies across disciplines and historical periods. Other theoretical virtues mentioned by de Regt are visualizability, causality, continuity, and locality, but he distinguishes as the two basic ones empirical adequacy and internal consistency, claiming that in choosing a theory there is a trade-off between these basic virtues and the others. The value that scientists attribute to the cluster of qualities of a theory that facilitates its use de Regt defines as "intelligibility" of a theory.

This recognition of the significance of theoretical virtues in theory choice is reflected in the way the notion of "objectivity" is reformulated by Longino and Douglas, who argued that a "strong", value-free objectivity of the kind adopted by Hempel, is unattainable and unrealistic. As far as "objectivity" refers to the individual scientist's thought processes de Regt adopts Douglas's notion of "detached objectivity," according to which evidence should not be disregarded in favor of theoretical virtues, but rather these virtues should be consulted when evidence does not speak unambiguously. On the other hand, in social processes objectivity is established, as Longino has argued, either when there is agreement within the community (concordant objectivity) or when–after an initial disagreement–consensus is achieved by means of critical discussion (interactive objectivity).

This reformulated notion of "objectivity" allows de Regt to claim that his account of understanding is not "subjective" in the sense of "varying across individuals," which was used by Hempel to dismiss the philosophical relevance of "understanding," but is, in fact, "objective" in the sense of being "detached", "concordant" and "interactive," and hence "varying across scientific communities and historical periods". Such variability is something, which, as de Regt insists, corresponds to the reality of scientific practice and to the testimony of historical record.

3.2 The variety of the models of explanation

Variability in the ways understanding is delivered is characteristic also of the models of explanation established within the field of the philosophy of science. De Regt's critical examination of these (chapter 3) aims to show that each of them relies on plausible intuitions of how understanding is achieved, but none of them can claim the position of a universal account. Thus, though unificationism (Hempel, Friedman, Kitcher) does not pose restrictions on the form of understanding-providing theories, the historical record shows that causality and visualizability have also been considered as essential for achieving understanding. Wesley Salmon's attempt to establish causation as the privileged road to scientific understanding also faces difficulties, according to de Regt – he points to domains of science where causal analysis is not applicable (quantum theory) or where though prevalent, it may not always be preferred (biology); finally, sometimes it is applicable in principle but yet not preferred by scientists (the explanation of the special relativistic Lorentz contraction). De Regt refers to the alternative causal models of explanations such as Woodward's and the ones of the new mechanists (Machamer, Darden, Craver). De Regt draws attention to the diversity in all these commonly labeled "causal" approaches – whereas Salmon and Strevens claim that causal analysis reveals hidden structures of the world (in Salmon, 1998; Strevens 2008), Woodward concludes that understanding is achieved not when one gets the ontology right, but when one knows the behavior of systems (Woodward, 2003); and, finally, the new mechanists' approach employs not only causality, but also visualization and locality (Machamer, Darden, and Craver, 2000).

De Regt also examines Salmon's attempt to reconcile the causal-mechanical and the unificationist models (Salmon, 1998), as well as Railton's "ideal explanatory text" thesis (Railton, 1981). Salmon's attempt, de Regt argues, does not solve the problems with quantum theory and with the Lorentz contraction, while Railton's thesis implies that there are objective, universal, and immutable criteria of genuine understanding, a notion that conflicts with the historical record and with scientists' own beliefs and attitudes – understanding, then, may be achieved by various types of explanations.

De Regt's conclusion is that though all these various accounts reflect our intuitions of what understanding consists of, an overarching theory is required that can accommodate them as different legitimate roads to the achievement of understanding. He claims that his theory successfully meets this requirement.

3.3 De Regt's contextual theory – CUP and CIT

Having defined 'intelligibility' as the value that scientists attribute to the cluster of qualities of a theory that facilitates its use, de Regt formulates two other basic notions: criterion for understanding a phenomenon (CUP) and criterion for the intelligibility of a theory (CIT). Thus, according to him, a phenomenon P is understood scientifically (UP) if and only if there is an explanation of P that is based on an intelligible theory T (UT) and that conforms to the basic epistemic values of empirical adequacy and internal consistency. To possible charges that this is a "theory-dominant" approach de Regt responds that he shares Giere's more liberal view of theories as collections of principles that provide the basis for the construction of models (Giere, 2006). CUP is pragmatic since it involves the notion of intelligibility, which is pragmatic itself – whether a theory is regarded as intelligible does not depend only on the theory, but on the scientists involved and on their skills and background knowledge. Pressed to balance between the requirement for context-dependency and not to qualify "intelligibility" as a matter of taste, de Regt formulates the criterion for the intelligibility of a theory (CIT), which states that a scientific theory T is intelligible for scientists (in a particular context) if they can recognize qualitatively characteristic consequences of T without performing exact calculations. De Regt is quick to point out that the criterion concerns theories formulated in mathematical terms, as it is usually the case in the physical sciences; he clarifies that this does not imply the replacement of exact calculation because mathematical techniques and logical rigor are indeed essential in modern science.

Relating "intelligibility" to the scientists' ability to recognize qualitative consequences makes this notion a measure of how fruitful a theory is for the construction of models by scientists. The contextual nature of "intelligibility" is clear since this recognition of a theory's qualitative consequences requires an appropriate "match" between the skills of scientists and the theory's qualities (e.g. visualizability, causality, unification, etc.). Referring to the various ways understanding is provided by the standard models of explanation, de Regt characterizes the qualities of a theory as "tools" for generating such qualitative "predictions". Thus, as an illustration of the function of visualization, de Regt refers to the use of the MIT bag model, which helps hadron physicists to understand quark confinement by representing hadrons as "elastic bags". But, as de Regt admits, familiarity with and intuition for the behavior of the solutions of the mathematical equations used by scientists can also allow for qualitative predictions. Causal reasoning, on the other hand, provides understanding to the extent that it allows scientists to predict how the systems under study will behave under particular conditions and not because it reveals the underlying mechanisms of the world.

4. Understanding Scientific Understanding – the history

The book's second part consists of detailed descriptions of three episodes in the history of science that involved explicit debates on the issues of understanding and intelligibility. These are: the 17th-century debates on the acceptability of Newton's gravitational forces, the widespread use of mechanical models in the second half of the 19th-century and the controversy between Maxwell and Boltzmann over the specific heat anomaly, and, finally, the issue of visualizability in quantum physics as it was first disputed by Schroedinger and the representatives of the Copenhagen school and later, as it was utilized by Richard Feynman in his diagrammatic approach.

De Regt's first case is presented as a solution to the confusion which, according to him, characterizes the standard historiographical treatments of this same episode. On the one hand, there is the positivist approach of Ernst Mach and Philipp Frank ,who regarded intelligibility as a psychological illusion, resulting from scientists' familiarity with a theory (in Mach, 1872, 1911; Frank, 1957) – since for Mach and Frank it is only a theory's empirical success that matters, they viewed metaphysically motivated opposition to Newtonian gravity as a hindrance to scientific progress. On the other hand, James Cushing agreed that Newtonian formalism's empirical success was the reason for the acceptance of acting-at-a-distance forces, but he argued that Newtonians did not truly understand gravity; this was only achieved 200 years later by Einstein and his theory's local and causal account (Cushing, 1994).

In response to this historiographical 'standoff' de Regt applies the theoretical tools of his contextual theory and distinguishes between metaphysical intelligibility and scientific intelligibility. Thus, contrary to Mach and Frank, he points out that metaphysical intelligibility was important not only for Newton's opponents, but for Newton himself – he also tried to determine the metaphysical cause of gravity, but unlike his opponents he did not remain committed to Cartesian corpuscularism and was willing to look for alternative doctrines. However, Newton also separated methodologically metaphysics, physics, and mathematics, allowing him to develop a theory of gravitational forces that did not account for their causes – a natural phenomenon was considered explained when a mathematical model was provided. Again, contra the positivist interpretation which saw metaphysics as an obstacle to scientific progress, de Regt insists on the positive role of Cartesian metaphysics for the development of physical theories. Cartesian corpuscularism not only provided an ontology that was considered inherently intelligible, but it allowed for qualitative reasoning about phenomena in terms of visualizable mechanisms (e.g. the billiard balls collision analogy). When this was combined with a Galilean purely kinematical conception of motion the result was the mathematical (geometrical) representation of phenomena in the mechanics of Christiaan Huygens. That is how, according to de Regt, the positivist approach ignored intelligibility's epistemic significance.

On the other hand, contra Cushing's criteria of intelligibility, which he qualifies as too static, de Regt argues that Newton's theory was indeed intelligible to the ones who adopted it; allowing for qualitative reasoning in terms of forces acting at a distance, it facilitated the construction of explanations, e.g. of the tides, of the moon's motion, etc. Newtonian theory's final triumph was due to its fertility – scientists did not just grow accustomed to it, but they acquired the necessary skills in order to use it effectively in constructing explanatory models of phenomena.

One focus of the book's second case study is the instrumental use of mechanical models as tools for understanding. For famous 19th-century scientists such as Thomson, Maxwell, and Boltzmann the realism of models was of little concern (Maxwell's position changed over time), what mattered was that models facilitated research. As concrete, tangible constructions these gave Thomson the ability to visualize and manipulate the object under investigation, while Maxwell's adoption of the approach of physical analogies led him to significant discoveries in electromagnetism; finally Boltzmann's Bildtheorie provided the framework of his pragmatic notion of what it means to understand a mechanism, namely, to be able to handle it correctly and know what effects certain manipulations would bring. Another focus of this chapter is the non-deductive character of model construction, as well as the significant role of judgment in this process, as illustrated by the controversy between Maxwell and Boltzmann over the specific heat anomaly. Neither entailed by the kinetic theory nor derived from experimental data, Boltzmann's 'dumbbell' model of diatomic molecules was the product of approximation and idealization. The significance of judgment was brought clearly forth by Maxwell's rejection of the model - his criticism focused on the issues of empirical adequacy and internal consistency, and the disagreement between the two scientists shows, according to de Regt, that they weighted these theoretical values of the model differently, with Boltzmann espousing practical success as the only criterion of correctness.

De Regt's claims about the significance of the virtues of a theory not only for its acceptance by the scientific community, but also for its successful application are illustrated by the book's last case study, which examines the issue of Anschaulichkeit (standing for both "visualizability" and "intelligibility") in the field of quantum mechanics. Schroedinger's emphasis on a theory's visualizability, that is, on its formulation within a space-time framework and, hence, his employment of wave mechanics, facilitated the adoption of his approach by the majority of physicists; they found Heisenberg's matrix mechanics much less accessible. But this also affected the theory's application – as de Regt argues, Schroedinger's approach initially proved to be more successful than Heisenberg's alternative. However, as de Regt's pluralist position implies, understanding can be achieved by following different roads. This is what is argued for by the description of Pauli's insistence on the inapplicability of the concepts of classical physics in the atomic domain, and hence, his rejection of Anschaulichkeit as visualizability via mechanical models. Pauli's conviction that new concepts, even if not visualizable, could become anschaulich as a result of scientists' becoming familiar with them inspired Heisenberg's reformulation of Anschaulichkeit as the "ability to think qualitatively through the experimental consequences of a theory [without contradictions]". This reformulation, as de Regt points out, provided the foundation for his own articulation of CIT. The function of visualizability as a conceptual tool for the construction of explanatory models is again illustrated by the episode of the discovery of electron spin – completely in the spirit of the old quantum theoretical approach, the discovery was the result of Goldsmit's and Uhlenbeck's skills for visualization. Pauli's reluctant surrender to this solution shows that he could not deny that the spin hypothesis successfully accounted for the empirical data; soon he found a way to interpret it within the framework of his own highly abstract approach. And yet, even today as de Regt argues, the concrete picture of rotation facilitates the understanding of electron spin. De Regt's account of the dispersion of Feynman's diagrams, which provided visualizable alternative to Schwinger's and Tomonaga's mathematically rigorous formulation of quantum electrodynamics, again emphasizes the significance of visualization as a valuable aid in understanding in physics. Feynman's diagrams were not realistic representations of physical processes, yet they proved to be useful tools for making calculations and solving problems–tools that required the acquisition of specific skills for their use and that proved to be applicable in contexts outside that of their original development.

5. Understanding Scientific Understanding – scope, normativity, and relativistic implications

The book's concluding part addresses three issues: that of the theory's scope, of its relativistic implications, and of its normative status. Since it is the second issue that has drawn much attention and critical fire in responses to de Regt's formulation of the theory in his earlier articles (see Bangu, 2017; Khalifa, 2012; Psillos, 2017; van Camp, 2014), here I discuss it last by drawing on de Regt's position as it is formulated also within the book's main body.

De Regt admits that he developed his theory with a focus on the natural sciences, and thus its criterion of intelligibility of theories (CIT) is designed for mathematized theories; he suggests that this may make it applicable to theories in fields such as economics and some branches of psychology and cognitive science to the extent that these are mathematically treatable. De Regt does not overlook the verstehen-erklaeren debate in the beginning of the

20th century or neglect to clarify that his theory does not argue for the privileged status of "understanding" as an approach specific for particular sciences; his approach focuses on understanding as related to explanation in general. Yet, he argues, his theory has drawn attention to the significance of understanding even for the natural sciences by highlighting the role of value and judgment in the construction and evaluation of scientific explanations. He admits that the contextual way in which understanding is achieved is reminiscent of the schema of the hermeneutic circle: first, having particular training and background theoretical commitments, scientists prefer theories with virtues that correspond to their skills and use them in order to construct explanations (UT); then, if successful (success here is due not only to theories' intelligibility, but also to their conformity to the basic scientific values of empirical adequacy and internal consistency), these explanations are taken as confirming scientists' understanding of phenomena; finally by using the same skills that were needed for the initial theoretical construction, scientists employ the explanations in further application, extension, and refinement of their knowledge, and thus improve their understanding of the field under examination (UP). The circularity involved here, claims de Regt, is inherent to scientific practice itself.

As far as the normative status of his theory is concerned, de Regt distinguishes between two types of normativity–prescriptive and evaluative–and argues that it is to the latter that his approach is committed – it does not specify rules that scientists should follow in order to achieve understanding, but it does clarify why in a given context certain theories are more successful by suggesting a test for their intelligibility: the CIT. Qualifying his approach as belonging to the HPS tradition, de Regt claims that his theory goes beyond the mere historical description – it identifies and explicates within scientific practices norms and criteria for understanding, thus constructing a general philosophical framework for the interpretation and explanation of historical episodes.

In opposition to anti-realism, which claimed that theories are merely tools for description and prediction of phenomena, realists, as de Regt points out, postulated that genuine understanding can be produced only by theories that are (at least approximately) true descriptions of an underlying reality. However, as the author of *Understanding Scientific Understanding* argues, scientific practice, as well as the history of science, with its pessimistic induction-reading, suggest that this connection between understanding and truth should be severed. As far as scientific practice is concerned this is what the widespread use of unrealistic or false models and assumptions shows – de Regt lists examples from economics, ecology, biology, and neuroscience. Thus, the aim of scientists is the manipulation of models, which allows for inferences to be made regarding the behavior of the system under investigation. This manipulation is always related to particular explanatory purposes and levels of description, and thus what matters is not that the representation of the target system is literally true, but that it suits the intended purpose. Moreover, even realistic depiction of a complex system may sometimes prove to be an obstacle to scientists' goal of predicting the system's behavior, and thus, to be an obstacle to scientific understanding. De Regt explicitly adopts Ronald Giere's perspectivist approach to scientific theories and models, according to which these can be compared to maps – like the latter, the former do not aim at providing a fully realistic picture and their truth is not unqualified objective truth, but rather truth relative to a particular context and purpose. That is why, de Regt claims, theories that we consider "outdated" or models that are incompatible can still be used by scientists, as this is the case, e.g. with the outdated Newtonian mechanics and with the incompatible models of water that represent it either as a collection of molecules (solvent) or as a continuum (fluid). Here, de Regt makes the provocative claim that in principle it is not impossible to use even rejected theories, such as the phlogiston theory, in order to achieve understanding; what makes it impossible is not that this postulated entity does not refer to anything in nature, but that there is no context in which a phlogiston explanation is empirically adequate and more intelligible than an oxygen explanation.

In response to charges in anti-realism de Regt argues that the context-dependency of understanding postulated by his theory does not entail relativism about science as a whole, since he does provide overarching criteria that indicate when understanding has been achieved. This is the criterion of understanding a phenomenon (CUP), which takes into account not only the intelligibility of a theory, but also its conformity to the basic epistemic values of empirical adequacy and internal consistency. Adopting Thomas Kuhn's response when his own approach was criticized as relativistic (in Kuhn, 1977), de Regt agrees that intelligibility varies from one scientific community to another, since the acquisition of particular skills is involved, but that it is such values as the above mentioned, that transcend communities' paradigms, make inter-paradigmatic communication possible, and provide protection against "unbridled relativism".

It is again these values that are used by de Regt in order to deflect the criticisms launched at another pragmatic approach, that of van Fraassen – contra van Fraassen's approach, Salmon and Kitcher had argued that further specification of explanatory relevance is needed since otherwise any relation can be explanatory in a given context (Kitcher and Salmon, 1987), and de Regt's inclusion of the basic scientific values of empirical adequacy and internal consistency allegedly meets the requirement of this specification. The vulnerability of van Fraassen's approach is related, de Regt argues, to the distinction between the epistemic and pragmatic dimensions of science and to the assumption that the epistemic aspects of a situation being explained are pre-given and independent of the pragmatic aspects, that is, the concerns and interests of scientists. Thus, scientific relevance (epistemic dimension) and explanatory relevance (pragmatic dimension) seem to be separated, and van Fraassen does not specify objective criteria for the latter; hence, Kitcher's and Salmon's critique.

De Regt claims that his aim is not to defend anti-realism, but to present a more sophisticated picture of the relation between realistic representation and explanatory understanding.

6. Conclusion

De Regt's *Understanding Scientific Understanding* does not present the reader with a new, previously unknown theory, but collects its author's work on the notion of "scientific understanding" as it was developed over the years. However, the book is not a simple collection, but a presentation of de Regt's approach as a structured whole, which unfolds from a critical identification of deficiencies in the traditional dismissive qualification of "understanding" as subjective and psychologistic to a positive philosophical account of this notion.

Thus, the book allows for a clear overview of the proposed theory's main constitutive claims and of their positioning in the overall argumentative structure, which helps for the localization of points of tension, loci for a critical discussion.

One such point is the way "understanding" is "operationally defined", as van Camp qualifies it, as an ability (van Camp, 2014) – by referring to the performance of a deduction (Hempel's own deductive model), to the discovery and application of the formula of a mathematical series (Wittgenstein) and to the construction of a deductive proof in logic (Brown) – de Regt relies on our intuitions about the connection between understanding something and being able to use it. However, intuitions can pull us in different–even opposite–directions, as this is illustrated by the debate in epistemology about the relation between understanding and knowledge (particularly telling is the divergence of interpretations of Kvanvig's "Comanches' domination of the southern plains" thought experiment, in Kvanvig, 2003; Grimm, 2006, 2014; Pritchard, 2009; Greco, 2014).

Another point of tension is the notion of "objectivity," which characterizes the relation between the inquirer and the object of inquiry. This relation is presented by de Regt as mediated by the fictive instruments of models/theories and its constructed nature is at the basis of his claim of the contextuality of understanding and, hence, of its unavoidably pragmatic character. This relation is articulated as consisting of understanding a theory (UT) and understanding a phenomenon (UP). A certain ambiguity can be detected here, which is exploited by van Camp in his critique of de Regt's position. On the one hand, de Regt insists on the necessity of UT for UP and it may be argued that this necessary connection makes the borders between the two not easily distinguishable. This closeness between understanding a theory and understanding a phenomenon is evident in de Regt's comments on Humphreys distinction between primary and secondary understanding (Humphreys 2000), the former being the understanding of a phenomenon achieved by a scientist by means of research, and the latter is the understanding gained by fellow scientists when this research's results, that is, the primary understanding, is being communicated to them – according to de Regt the act of understanding a ready-made theory involves following the steps of its inventor and reproduction of the original line of reasoning. On the other hand, de Regt explicitly distinguishes UT from UP and he defines "intelligibility" operationally (as the ability of drawing qualitative consequences), whereas "explanation" is defined in a unificationist way (as argument that connects answers to a why-question with other accepted items of knowledge); thus, an explanation explains when it meets the additional criteria of empirical adequacy and internal consistency. Van Camp takes this difference as showing that in de Regt's account understanding is decoupled from explanation.

It may be argued that the distinction between understanding a phenomenon and understanding a theory is also at the basis of the critique of Stathis Psillos, who insists that it is only the latter that is audience-oriented. Thus, the contextual nature of "understanding," as well as de Regt's claim that the link between understanding and truth should be severed, provoked qualifications of his position as "neo-instrumentalist" (Psillos) and as entailing "almost extreme subjectivism and relativism" (Bangu). The position presented in *Understanding Scientific Understanding* relies, similarly to other pragmatic approaches to "understanding", such as that of Jean Faye (2014), on the use of models in scientific practice, as well as on the pessimistic-induction reading of the history of science. That is why scientific realists who oppose non-factive accounts of understanding, such as Psillos, insist on the truth quam proxime of models and point to the continuity in the history of science, e.g. as it is illustrated in Einstein's recovery of the Newtonian theory of gravity as a limiting case of his own General theory of relativity (in Psillos, 2017). Thus, despite his claims to the contrary, de Regt's position is taken to imply anti-realism.

However, the pessimistic-induction reading of the history of science is not just an argument to which de Regt simply refers in support of his position; as the case studies in *Understanding Scientific Understanding* show, he examines closely the historical record, which both inspires his theoretical account of "understanding" (the main function of the second and the third case studies) and provides testing grounds for this notion's application (the first case study). This hermeneutical dynamic corresponds to de Regt's characterization of the process of scientific inquiry as one following the curves of a hermeneutical circle, but it may also raise questions characteristic of the debate on the HPS approach (see Pitt, 2001 and Schickore, 2011). Thus, it can be an object of historically informed debate to what extent de Regt's introduction of two types of intelligibility–metaphysical and scientific–in his study on the acceptance of Newtonian forces is not anachronistic, a result of the "intrusion" of his theoretical account of "understanding" upon his historical hermeneutic. And yet, the resulting narrative in *Understanding Scientific Understanding* seems to be characterized by greater historical sensitivity than the alternative ones of Frank, Mach, and Cushing.

Thus, *Understanding Scientific Understanding* represents a complete account of the position de Regt has been elaborating over the years, an account that draws on fields such as scientific representation, objectivity, models of explanation, scientific practice, explicit and implicit knowledge; moreover, it convincingly combines philosophical analysis with historical narrative. That is why, in my opinion, it may become a reference source for one of the pragmatic approaches in the recently reinvigorated debate on scientific understanding, but also a valuable contribution to the growing literature of HPS.

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