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The Relevance of Judgment for Philosophy of Science

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Judgment and the quest for knowledge in science

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Abstract. Although we tend to view science as focused on facts and logical analysis of objective information, assessing scientific proposals involves complex discussions based more on judgments than formal rules, especially in the more general disciplines. This paper explores the matter using as a launchpad two related episodes representative of current science. One focuses on the introduction and critical reception of Albert Einstein's theory of special relativity, notably how it led to reconsidering epistemic values in accepting and rejecting ideas. The second episode is Niels Bohr's defense of quantum mechanics in the Solvay Conference in 1927 and afterward, which uses Einstein's approach. These episodes transformed modern science. Their impact on epistemic values is a central topic of this paper. The results show how strongly legal-like deliberative thinking is consubstantial with contemporary science.

Background

The decline of logical empiricism in the 1950s revived interest in the character of scientific decisions. Some philosophers, notably Stephen Toulmin, noted that scientific verdicts typically involve a balance of gains and losses achieved through careful judgment, like in the practice and study of law. In *The Uses of Argument* (1958) and later in *Human Understanding*(1972), Toulmin discusses connections between jurisprudence and the philosophy of science, jurisprudence understood as the study of judicial decisions that cannot fully follow strict rules. The philosophy of science of the 1960s developed a growing consensus that the ideal of perfectly rule-governed rational deliberation does not fit contemporary scientific practice. One reason is that scientific proposals in a domain vary with respect to the benefits they provide. Scientists need to decide how much ground to give up on one front (for example, predictive power) in exchange for progress on another (for instance, descriptive simplicity). The examples used by Toulmin include Einstein's argument for the Special Theory of Relativity in the 1900s and, from a little later in the story, the debate surrounding the rise of Quantum Mechanics.

Between 1880 and the first years of the 20th century, high-precision experiments aimed at measuring the relative speed of the medium of light (the so-called "luminiferous aether") showed a systematic inability to achieve such a measurement. A view widely accepted at the time as a "truth of

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reason" dictated that light waves require a medium to arise and propagate. But whatever that medium was, relative to the devices used to do the measurement on Earth, the speed of light appeared not to change. Studies of empiricist epistemology helped to break the impasse. Especially the work of Ernst Mach (keenly read in some circles of theoretical physics) led Einstein to make a blunt proposal. Since the speed of the luminous medium resists empirical scrutiny, we should leave the ether intellectually aside and accept the speed of light as a universal constant. Though outrageously against both common sense and the conceptual basis of previous physics, this idea is a central tenet of Einstein's 1905 Special Theory of Relativity (SRT). SRT abounds in rebellious conceptual implications—notably the relational character of the "present time", which in STR is not the same across *all* reference systems (as it was in prior physics).

Einstein's train of reasoning on these fundamental matters was not properly rule-governed. Technically, his arguments were informal. Still, the disputes they generated did proceed in terms of explicit reasons open to criticism. Commenting on those disputes, Toulmin emphasizes the resemblance of the arguments at play to common law arguments, where often a loose procedure satisfactorily resolves the issue at hand. In the two historical cases mentioned, the soundness of the proposed strategy rested on future projections rather than synchronous evaluations. While the research was still in full flight, deciding which envisioned option will lead to more fruitful explanations could only be based on "rational bets."

Epistemic Values and Scientific Verdicts: Two Historic Deliberations

(1) The Special Theory of Relativity (STR). STR challenged some of the traditional metaphysical underpinnings of physics, radically changing the conduction of theorizing. One fundamental contribution concerned the relative weights of the virtues associated with "good theories" (notably, intelligibility, predictive power, and simplicity). Einstein's shift to a working-level (functional) conception of the ontology of waves was no less crucial. His description of light and electromagnetic waves abstracts the latter from the conceptual scheme that had been their traditional home, where light waves occurred as "modes of being" of the luminiferous ether, not as independent entities. The philosophical impact of this move on the "mechanical intelligibility" of electromagnetic waves is radical. Together, the two changes mentioned allowed Einstein to conceptually integrate the strange principles of STR with abstract versions of fruitful parts of Maxwell's theory. Here Einstein was investing intellectually in a strategy whose fertility and soundness (or lack thereof) could only be decided in the future. In STR, postulating the speed of light invariance favors epistemological empiricism and theoretical simplicity. This preference takes place at the cost of coherence with traditional metaphysics.

Neither scientists nor philosophers then (or have now) had a consensus on the strategy to follow, much less a formal rule for making quick decisions in cases like this. It took time to appreciate the scientific consistency and fertility of Einstein's choice, which remained the subject of intense reflection throughout the rise and fall of logical empiricism. The resulting deliberations led to insightful acknowledgments by historically oriented philosophers of science in the 1970s and 1980s. It was now clear that the acceptance and rejection of theories constitute a sophisticated form of value judgment. Another acknowledgment was that scientists disagree on the relative weights they assign to different epistemic values. Regarding the critical appraisal of STR, philosophical historians of science like Ernan McMullin (1983) showed how simplicity and consistency with background theories competed for primacy. This lack of fundamental evaluative consensus—he urged—explains why controversies, far from being rare in modern science, are a persistent and omnipresent occurrence, especially at the highest discursive levels[1].

(2) Quantum Mechanics. In foundational studies, Einstein's epistemological and methodological strategy for STR has remained strong. Early influences are apparent in the work of Niels Bohr—in his 1913 semiclassical model of the hydrogen atom and later in his contribution to the development of quantum mechanics. It appears prominently in Bohr's criticism of Einstein's, B. Podolsky's, and N. Rosen's 1935 rejection of the presumed fundamental character of quantum mechanics (the famous "EPR argument"). The influence of Bohr's revisionism is most noticeable in his appeal to a relational conception of dynamic properties, a response to EPR explicitly based on how Einstein's suspension of traditional metaphysical principles had advanced STR. According to the EPR argument, a system of two interacting particles will forever display a mysterious instantaneous interface. Specifically, an operation performed on one of them would instantly modify the state of the other regardless of how far apart they were at the time. Such an action involves entanglement between the two particles that contravenes previous physics—specifically, it goes against the classic principles of determination, separability, and spatiotemporal locality. And it is something we do not observe in everyday life. According to Einstein, Podolsky, and Rosen, the correct conclusion was that quantum mechanics is an empirically adequate but ontologically incomplete theory. In their view, the real world violates classical principles only at the surface level—at a deeper level lies a world of fully determinate, separable, and non-instantaneously interacting entities—a part of reality that quantum mechanics misses. The EPR argu-

[1]See, for example, Toulmin 1958; McMullin 1983,1989; Mary B. Hesse 1974, 1980; and Dudley Shaper 1984, 1987.

ment notwithstanding, Bohr stuck to his position, backing it with arguments drawn from early "Einsteinian" revisionism. The result was a way of thinking about physics—diffusely titled "The Copenhagen Interpretation" (CI).

On the one hand, CI posited the existence of limits to physical intelligibility. On the other hand, it led to extraordinary scientific fecundity in numerous areas of physical application—general quantum mechanics, atomic and molecular physics, condensed matter, and quantum field theory, among others. On the downside, the limits placed on intelligibility seemed highly arbitrary. A significant dark aspect of the proposed doctrine is the privileged epistemological and ontological status given to measurement processes. CI blocks the description of measurements by putting them under a veil of mystery. Instead of explaining what happens when they are performed, and more generally, outside the range of natural perception, all CI offers is "black box" approaches based on a mysterious rule—the quantum algorithm. Like Einstein, numerous physicists and thinkers considered the explanatory poverty of the Copenhagen approach appalling. Critics saw a commitment to obscurantism in CI. It was not acceptable, they argued, to have such poverty enshrined in the theory that allegedly provided the most fundamental physical explanation of material systems. The EPR argument expresses their intellectual discontent.

Realist Revivals

Frustration with CI intensified in the 1950s and 1960s. Developments such as Bell's theorem and its experimental adaptations made it conceivable to explore empirically whether nature respected the classical principles of determination, separability, and locality. Many of the first experiments conducted favored quantum mechanics. Subsequent tests confirmed the trend, strongly suggesting that it was impossible to maintain the three principles mentioned—at least one had to go. By the end of the 1980s, there was broad agreement that experiments based on generalizations of Bell's theorem had tipped the epistemological balance towards quantum mechanics against both classical metaphysics and the interpretive restrictions imposed by CI. "Ontic" proposals—so-called because they take the quantum state as representing something physically real—prospered. One result was a revival of interest in the ontology and foundations of quantum mechanics, now detached from radical empiricism.

Since the mid-1980s, three approaches have dominated ontic proposals (see, e.g., Cordero 2001, 2019): Bohmian Mechanics (BM); Many-Worlds Quantum Mechanics (MW), pioneered by Hugh Everett in the 1950s; and spontaneous collapse theories that postulate stochastic discontinuous changes of the quantum state (SC)[2]. Critics found that the first versions of these ontic

[2]E.g., the proposals by GianCarlo Ghirardi and his collaborators.

proposals needed more clarity and coherence. Improved offers, developed since 1990, draw on working-level (functional) approaches and effective (as opposed to exact) descriptions of the ontologies of ordinary quantum mechanics and quantum field theory. The ensuing ontic proposals describe physical worlds that differ among themselves and yield some divergent predictions, making it possible, in principle, to choose between them in the laboratory. Unfortunately, however, all the disagreements predicted occur in areas empirically inaccessible to present technology.

Which of the mentioned ontic proposals is more convincing? For now, none of them wins in terms of achievable predictions. In practical terms, the three approaches are "effectively equivalent." They differ, however, concerning virtues other than predictive power, mainly simplicity, epistemic modesty, range of application, fertility, and explanatory power. These differences invite divergent selections of the "best option" (Cordero 2001, Callender 2020), highlighting the ongoing debate and the need for further research in our dynamic field.

Bohmian Mechanics rejects the Copenhagen Interpretation and focuses on what is physically real instead of merely "observable"—it concentrates on "beables", not "observables". "Beables" are objects held to be elements of reality whose objectivity does not depend on "observation." They are things or properties existing in the physical world. In BM, the beables are particles (entities that always have precise positions). According to some thinkers, BM is preferable to the other ontic proposals because, as the claim goes, BM surpasses them in clarity and explanatory power (see, for example, Jean Bricmont 2016).

On the other hand, as Craig Callender (2020) notes, advocates of Many-Worlds—MW (notably David Wallace)—underscore that only their theory explains all known physical phenomena. According to Wallace, this consideration makes MW the winning option based on the diversity of phenomena it explains. Critics disagree. A recurring charge against MW is that it makes the concept of probability too problematic, unlike theories such as BM or SC. In turn, SC defenders emphasize the extravagances MW and BM go to save the ontologies they postulate (effectively parallel worlds and a surreal Bohmian particle ontology, respectively). By contrast, SC theories—assert their defenders—are the most economical and straightforward. For this reason, they urge SC theories to be preferred and prioritized when selecting the best ontic proposal. In the current disputes over ontic quantum theories, the values invoked by the contending parties compete, much as they had earlier on in the deliberations on the Special Theory of Relativity and the Copenhagen Interpretation.

Which of the contenders provides the best approach? Again, as with STR and later CI in the 20th century, the question invites judicious deliberation.

The values at stake pull in different directions. Admittedly, however, our understanding of the physical circumstances and epistemic conditions may change in the future. For example, it might become feasible to discern experimentally between the conflicting ontologies, or one might prove more fruitful than the others. Still, whatever happens in the future, the episodes highlighted in this and previous sections exemplify the priority of judgment in scientific decision-making and its diachronic and refutable character..

Realism and Inference to the Best Explanation

In *The Structure of Scientific Revolutions* (1962), Thomas Kuhn argued against linear scientific progress, emphasizing that each theory has concepts that differentiate it from other theories. This circumstance, he urged, makes expressions extracted from different theories "incommensurable" because one cannot legitimately compare the terms involved. And, he went on, even when the concepts involved don't vary, realist interpretation is overshadowed by the availability of multiple theories that explain the relevant data, even within the same framework of epistemic values. These ideas became central to the epistemology of Paul Feyerabend (1975a) and the doctrine of "underdetermination of empirical theories by experience" (UTE). His claims of radical dependency of reference on the conceptual networks of theories led to subjectivist and relativist attitudes that gained strength in the 1970s and 1980s. Passionate debates took place about the viability of scientific realism within the new historical turn in the philosophy of science.

One broad sector of scientific realists stressed the justificatory role of explanatory power, arguing that explaining a phenomenon (or theoretical structure) makes it more plausibly truthful. The participating realists presented "Inference to the best explanation" (IBE) as a form of "abductive" reasoning that substantiates a hypothesis on the premise that it provides the best explanation for the available data. Richard Boyd (1981) highlighted the historical success of IBE and shaped the approach for a generation. He advised that the methods used by modern scientists to design theories and choose between them have consistently led to instrumentally adequate proposals. In Boyd's view, the reliability of the recommendations thus endorsed is*explained* by assuming that they are approximately true. Boyd uses abductive argumentation to claim that the abductive methodological rule is probably reliable. Although the argumentation is blatantly circular, it allegedly leads to better and more fruitful explanations. If that is correct, then the circularity involved is "virtuous" rather than "vicious" (a type that only gives empty explanations). For this reason, realists in Boyd's camp think IBE deserves rational acceptance.

Like McMullin, IBE proponents point to features that—they think—enhance the plausibility of explanations. Those features include descriptive depth beyond the observable level, domain breadth, simplicity, unifying power, predictive accuracy, internal consistency, external consistency, fertility of results, and other epistemic virtues already noted in this paper. From this perspective, the crucial point is that each instance of IBE generates a certain amount of justification for the total theory under evaluation. Following Matthias Egg (2020), I will call this line of the IBE project "IBE-theoretical" (IBE-T).

Nevertheless, antirealist complaints make trouble for IBE arguments in the contemporary debate. This concern is particularly apparent in the underdetermination of theories by experience—the UTE charge. UTE problematizes the realism inherent in IBE-T. As in the noted ontic theories of quantum mechanics, the epistemic values identified by IBE-T proponents generally lead to multiple selections of "best theory", all compatible with the available data. At any rate, no matter how strongly empirically adequate an explanation may be, it will not admit realist commitment unless it is free of competitors as successful as her. At best, then, the IBE approach needs work.

A complementary line of objections challenges the presumed realist link—the idea that the empirical success of a theory indicates truth content. The most influential project of this type elaborates on Larry Laudan's (1981) confutation of convergent realism. Here, antirealists use the history of science as a basis for skeptical inductions (SI). Laudan's refutation of the supposed realist link invokes the numerous theories that, having shown splendid success, then proved not only wrong but wrong at the level of their central assertions.

The most compelling realist responses to SI make two claims. They accept that theories taken as whole descriptive constructs probably get something wrong. But then, they also try to preserve a limited version of the link between empirical success and truth, now confined to certain parts of the theories. The resulting realist projects follow the umbrella term "Selectivism;" they counter SI and UTE objections by identifying truthful parts in empirically successful theories. A typical example of a selectivist application is how Einstein's STR abstracts electromagnetic waves from the luminiferous ether and much of the underpinning ontology of nineteenth-century physics.

Selectivism makes for a more restrictive variety of IBE than IBE-T. While the latter selects complete theories (which include the entities, laws, and relationships proposed by each theory), IBE-selectivist limits the descriptive content to theoretical parts that satisfy strict selection criteria. One problem, however, is the difficulty of prospectively identifying the sought theory parts—i.e., without vitiating the project with merely retrospective identifications. Critics thus urged selectivists to clarify and refine their strategy. Recent positions have enhanced immunity to anti-realist criticism (Cordero 2017, Egg 2021), but challenges remain, notably the theory parts selected still face UTE-type charges. Realists currently focus on two related projects: causal selectivism and working-level (functional) selectivism. Here, I will focus on causal realist approaches (the following conclusions also apply to functional approaches; see Cordero 2017).

Causal realism (IBE-C) continues contributions that began in the 1980s, particularly from influential figures such as Nancy Cartwright (1983). The most recent and influential works in this field include those of Anjan Chakravartty (2007), who has made significant contributions to the understanding of causal properties, Mauricio Suárez (2008), and Matthias Egg (2021), among others. Chakravartty, for instance, emphasizes that causal properties confer dispositions for relationships—specifically behavioral dispositions for particular entities with the said properties. From the IBE-C perspective:

(i) The entities and processes with which we interact causally are generally better established than those that figure in theoretical hypotheses (Cartwright 1983).

(ii) The justification for accepting a causal hypothesis comes from concrete facts and low-level laws established over limited regimes. Causal interaction attributions can convince independently of considerations in terms of ordinary epistemic virtues.

(iii) Causal justification is generally more robust than theoretical justification (Suárez 2008). To the extent that this is so, claims with causal backing deserve a more substantial realistic commitment than those with merely theoretical support.

For the above reasons, the IBE-C strategy limits realistic engagement to specific UTE-free material assertions (as opposed to global skeptical UTEs).

IBE-C Thesis: Theory parts with causal justification can be defended against solid versions of the anti-realist critique; those parts form a hard core of realist commitment.

The Primacy of Judgment

The highlighted advances of selectivism seem to improve the scientific realism project significantly. Still, no matter how safe they appear, one can think of empirically equivalent competitors for virtually all substantive hypotheses. Consider, for example, the "brain in a vat" hypothesis given prominence by Hilary Putnam (1981), according to which we are not what we think we are: we are disembodied brains living in vats filled with nutrients and connected to a computer that some external operator handles.

Are we what we ordinarily think we are, or do we live in a simulation? How do you answer such a question? There is no shortage of proposals with similar skeptical force. As Paul Feyerabend pointed out in the 1970s, choosing an answer is not exactly something we can resolve empirically. How are we then to recognize and follow the truth? Encouraging overreaction, Feyerabend (1975b) advised that the idea that we should "follow the truth" is a statement whose truth is nothing but a dogmatic ideology. Whatever one thinks of the latter recommendation, the critical point is that not even the most compelling scientific theories are free from insidious, skeptical UTE charges. The resulting skeptical objections apply to all IBE strategies, including the most substantial forms of IBE-C (Egg 2021). The same applies to selective working-level, functional realist claims and other promising updates to scientific realism.

However, there is one pragmatically rooted response to radical suspicions like those just voiced. It consists of noting that extreme skeptical variants appeal to ways of thinking that question the availability of evidence for more than the specific hypotheses they target. Their corrosive effect blows all empirical knowledge equally. According to scientific realists like Dudley Sapere (1984, 1987), the appropriate response is to reject such skeptical moves outright—we should drop all those hypotheses that result in general skepticism if taken as relevant options. This response appeals to a historically grounded epistemic value: *non-specific doubts (global or metaphysical), far from promoting our epistemic goals, ruin them.* In this pragmatist response, the mere logical possibility of doubting a theory does not constitute a reason to doubt that the theory is correct. It judiciously acknowledges the epistemic value of rejecting global (metaphysical) doubts as reasons for doubting specific claims about the world. In this way, scientific realism frees itself from objections of the UTE-skeptical variety.

Note that the proposed pragmatist turn does not free scientific realism from the need for deliberation. On the contrary, the suggested response places the rational justification of realist commitment explicitly in the realm of judgment. Pragmatist rejection of global doubts rests not on any formal procedure but deliberation. All naturalistic varieties of scientific realism rest irreducibly on deliberation. Admittedly, prioritizing judgment in epistemic assessments problematizes scientific objectivity, raising worries about the proposed realist move. The problematization at play need not be harmful, however. By making the values at stake explicit, deliberation can improve the quality of objectivity in at least two ways. On the one hand, it clarifies the values and rationale behind the competing positions. On the other hand, it links the selection to the long-term results of the competing proposals, especially regarding scientific fertility and intellectual coherence.

In appraising any substantive theory, it is not immediately possible to establish which competing option will, in the long run, suggest more and better explanations of the relevant facts or more fruitful extensions to previously unapproached domains of nature. As Toulmin noted in the 1950s, deliberative thinking of a legal nature is consubstantial with contemporary science. This paper takes Toulmin's proposal to heart. Confronted with a specific situation, scientists deliberate about when to apply and when not to use the maximum potential severity of the evaluative criteria forged by science. This prudence is not an incidental aspect of the scientific evaluation of theories and projects. It is an expression of the central diachronicity of the evaluative process.

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