Schematizing the Observer and the Epistemic Content of Theories, or Getting the Laboratory into the Theory

Erik Curiel

Lichtenberg Group for History and Philosophy of Physics (Bonn Universität)

Black Hole Initiative (Harvard University)

Quantum Information Structure of Spacetime Consortium

erik@strangebeautiful.com
http://strangebeautiful.com

(partially funded by an ERC Collaborator grant to Bonn
and a John Templeton Foundation grant to QISS)

The vague accuracy of events
dancing two by two with language,
which they forever surpass

William Carlos Williams
Paterson

So I suggest that the principal difficulty is not that of how to leave the theory outside the laboratory door, but that of how to get the laboratory inside the theory. ¶ Well, how <u>do</u> we do it? For of course we do put theory and experiment in relation to one another; otherwise it would be impossible to test theories, and impossible to apply them. It would also, I should add, be impossible to <u>understand</u> a theory, as anything but a purely mathematical structure—impossible, that is, to understand a theory <u>as</u> a theory of physics—if we had no systematic way to put the theory into connection with observation (or experience).

Howard Stein (1994, emphases his)
"Some Reflections on the Structure of Our Knowledge in Physics"

Outline

What a Theory Is

To Schematize the Observer

Why We Need to Do So

Valediction

What is the theory of general relativity?

Here is one way to make that question somewhat more precise:

> *What is the more or less secure fund of scientific knowledge that constitutes the theoretical and empirical content of the theory?*

The standard view:

- a theory is characterized in a strong sense by its family of "models"
- those models have intrinsic physical significance accruing to their formal structure independent of any consideration of how the theory is applied in practice (Tarskian or possible world semantics, sketch of representational capacities, ...)
- *tacit assumption* $\Rightarrow$ can cleanly separate knowledge encoded in the theory's pure formal machinery from all other components, including experiment, observation, ...—the *practical* *remainder*

this assumption comes out most clearly in the picture of semantics naturally and usually accompanying the standard view:

semantics is fixed by ontology's shining City on the Hill

all epistemology and methodology and other practical issues and considerations are segregated to the ghetto of the theory's pragmatics

Recall my formulation of the question "what is a theory?":

> *what is the more or less secure fund of scientific knowledge that constitutes the theoretical and empirical content of the theory?*

if fruitful and interesting, then general relativity can not consist of the theory of Lorentzian 4-manifolds, along with a few interpretive postulates or a family of Tarskian models or a class of possible worlds or a category-theoretic structure

- interplay between theory and practice (experimentation, observation, modeling, heuristic and approximative forms of argument, reconstruction of data to make it amenable to comparison with theory, that comparison itself, interpretation of the data and the comparison, . . .) is far more subtle, nuanced, complex and rich than we tend to appreciate
- $\Rightarrow$ the two are inextricably intermingled in a strong sense
- the sum total of a theory's scientific knowledge including its theoretical and practical components—its "epistemic content"—essentially includes knowledge we have gained, and could have gained only, through:
    1. practical modeling
    2. experimentation and observation
    3. heuristic and approximative argument
    4. and application of representations of such experiments and observations through heuristic and approximative argument
- such knowledge, moreover, cannot at bottom be cleanly separated from any knowledge grounded wholly in the theory's pure formalism

- why my formulation of the question is a fruitful sharpening and refinement: it is this sum of epistemic content that distinguishes general relativity as a *physical* theory from a merely mathematical structure
- a crucial component of that content consists in knowing how to—in Stein's phrase—"schematize the observer" in theoretical representations of experiments
- and indeed it cannot be had without models of experiments in which the observer is schematized
- I emphasize: my conception of knowledge not limited to anything like "justified true belief"
- it includes more importantly comprehension and understanding involved in explanatory practices, as well as practical knowledge (and art) involved in everything related to experiment

- for every physical theory (Navier-Stokes theory, general relativity, quantum field theory, *etc.*), we have very little detailed knowledge of generic solutions
- usually only exact solutions, only under conditions of perfect or near-perfect symmetry or some other unrealistic assumption (two bodies, no external perturbative influences, ...)
- then argue such solutions apply to real physical systems, because the approximation is adequate

That is to say: we have no real idea *at all*, in a representational sense, "what the world would be like if the theory were true or largely true of it", for any physical theory.

This becomes particularly clear when one stops to think, to really think hard, about the mind-blowing complexity and richness of texture of real physical systems in the world.

Take this bottle of water, seemingly in equilibrium with its environment. . . .

In light of my remarks about the paucity of our knowledge of actual solutions to our theories' equations in conjunction with the incomprehensible complexity of the world, therefore, to accept the standard view is to accept one of two options:

1. we stipulate by fiat that there is a family of actual (or possible, in some sense) physical systems, though we cannot identify most of them in practice, that are the ones represented by the solutions, and those are the models;
2. we stipulate by fiat that the family of solutions themselves (*e.g.*, vector fields on phase space) are the models, though we cannot represent them in anything like closed form or even identify almost any of them if they were to bite us on the ass.

Call this 'the standard view's dilemma'.

In both cases, we are saying:

- the overwhelming majority of the content of the theory is something we do not know
- are in fact nowhere near knowing
- and have good reason to think we will never know in anything remotely resembling thoroughness and detail

epistemologically speaking, either choice is an act of faith

Nonetheless, the story goes:

- a preternatural relation of subsistence among the formalism, the models, and the physical systems univocally and unambiguously fixes them
- that in turn gives rise to a magical relation of "reference" or "representation" zapping out from the formalism to latch onto the world

We, in our supernal cognitive puissance, just *know* this.

We are talking here of a Fichtean faculty of pure intellectual intuition that grasps without cognitive or perceptual mediation the Kantian *Ding an sich*.

Or more precisely, we are talking of nothing at all.

A semantic relation that is not known and cannot be known by humans in our current epistemic circumstances has no possible use in actual science and has no possible bearing on a fruitful and illuminating analysis of scientific knowledge.

- needed: a mechanism for bringing a mathematically characterizable situation in the world into physically significant contact with the formalism of theories
- an intermediary that identifies junctions where meaningful connections can be made between the two
- and so would embody the possibility of the epistemic warrant accruing to theories from such connection

$\Rightarrow$ <u>*schematizing the observer*</u>

By “schematize the observer” I mean something like:

> *in a model of an experiment, to provide a representation of something like a measuring apparatus, even if only of the simplest and most abstract form, that allows us to interpret the model* <u>*as*</u> *a model of an experiment or an observation*

This requires <u>*all*</u> other components of the practical part of scientific knowledge.

In actual fact, the experimental physics is treated separately as a discipline in its own right, that is partly an art: an affair of both knowledge and manipulative and perceptual skill. But the possibility of connecting this art with the theory is closely connected with a certain possibility within the mathematical structure that is the theoretical framework: . . . the possibility of representing experiments, and of representing the observer, "schematically." . . . I want to speak . . . of "schematizing the observer within the theory"; . . . the intention is . . . to secure empirical content—content within experience—for an abstract structure. ¶ . . . [S]o far as the fundamental theory is concerned—or rather, so far as mathematically defined structures and rigorous arguments are demanded—the "schematic" representation of observers, experiments, and observations, is, I believe, as far as we know how to go.

Howard Stein (emphases his), *ibid*.

- the meaning of scientific terms and propositions must rest on knowledge of the physical world
- and most of all on knowledge from controlled measurement, observation and experiment
- $\Rightarrow$ epistemic content accrues to a scientific theory through successful construction of representations of physical systems
- $\Rightarrow$ secure epistemic content of a theory must rest on meanings expressed in sound articulation of experimental knowledge
- $\Rightarrow$ at a minimum we must be able to construct in theories representations of actual experiments—to schematize the observern
- not just representations of physical systems *simpliciter*, in abstraction from actual experiments, as in the standard view

There are, as I have intimated, several reasons why I claim that schematizing the observer is required for an adequate philosophical analysis of the structure and semantics of theories and of scientific knowledge more generally. I discuss now four of them in more detail.

The first is a shallow but still important one:

- sometimes the observational process itself “distorts” the magnitudes measured
- proper computation of the “real” values the system’s properties requires explicit modeling of interaction between instrument system

The second is a middling deep one:

- quantitative results of measurements, even the best, inevitably deviate from predictions
- likewise, is inevitable imprecision in measured values
- such deviations largely come from systematic errors from idiosyncracy of experimental apparatuses and configuration
- the imprecision is inevitable artifact of the limited acuity of any probe
- to compute reasonable values for expected errors and imprecision (*e.g.*, to decide whether an experimental differs by an inadmissible amount from a prediction), one must often account for fine details of the apparatus and how it couples to the system

Thermometry provides an excellent example: different sorts of thermometers (bulbs of gas, pyrometers, inhomogeneous thermocouples, *et al.*) couple to systems in radically different ways, the fine details of which must be handled on a case-by-case basis in order to correct for the effects of such phenomena as convective currents in fluids.

The third reason is a deeper one:

- theory must provide guidance to experiment in design of new types of tools for probing novel sorts of phenomena and known phenomena in novel ways
- conversely, experiment must provide guidance to theory in modeling practically constructed novel ways of coupling to systems known and unknown
- $\Rightarrow$ theory must be able to represent the fine details of the apparatus as it is actually to be used in the experiment
- it is difficult to see how any epistemic content could accrue to theory in the first place if this interplay could not happen

The fourth reason is the deepest, and depends in part on the previous three:

- without understanding the fine details of how theories do and do not successfully model actual experiments, we cannot demarcate the regime in which the theory is appropriate and adequate—its *regime of applicability*
- it is *only* by dint of practical forms and aspects of scientific knowledge involved in schematizing the observer that we can determine a theory's regime of applicability

- the standard view gets right:
  the family of physical systems a theory appropriately and adequately treats is an essential component of the epistemic content of a theory
- the standard view goes wrong:
  it makes sense to characterize this family in the abstract, without recourse to and reliance on all the scientific knowledge we have pertaining to the theory and its applications
- to identify that family of systems, we need to demarcate the theory's regime of applicability
- to do that, we need to fix error tolerances, acceptable levels of precision, *etc.*, in our experimental practice
- to do that, we need real models of actual experimental techniques, representing the actual tools we have at our disposal for performing such measurements, for the regime of applicability changes over time with advances in practical knowledge
- $\Rightarrow$ we need to schematize the observer

Knowledge of the regime of applicability, however, embodies perhaps the most important part of the epistemic content of a theory—without it, we have no warrant at all for trusting our use of the theory, much less for understanding it *as* a theory of a particular class of physical systems.

Nothing in the theory's formalism can tell us this, without the input of knowledge that can be had only by experimental practices that require schematizing the observer in theoretical models.

If demarcating the regime of applicability did not depend on practical knowledge of the kind that changes—the current reach of experimental technique that determines fixed levels of precision and accuracy, the availability of approximative theoretical techniques and heuristic forms of argument to make calculations tractable, and so on—then there would be a fixed number, once and for all—say $3.14159265358\ldots \mathtt{x}10^{-6}\ \mathtt{cm}$—at scales smaller than which the representational capacities of Navier-Stokes theory breaks down.

But that is simply false.

It breaks down at different scales for different types of fluids under different conditions, and the increasing acuity and resolution of our measuring instruments, in conjunction with our increasingly powerful control of experimental error, both practically and experimentally, and the increasing sophistication of the models we can construct of our measuring devices and the fine details of their interactions with different Navier-Stokes fluids under different conditions, all mean that such numbers become ever smaller. They are not fixed *sub specie æternitatis*.

Thus, neither is the family of physical systems that a theory appropriately and adequately treats fixed *sub specie æternitatis*. I think this is right. A scientific theory is not a Platonic form. It does not exist independently of our actual epistemic state.

In virtue of the last two reasons, one cannot even define physical quantities—*e.g.*, temperature—without explicit schematic representation of the observer, much less have understanding of how to employ their representations in scientific reasoning. Without such a definition, however, any theoretical proposition referring to temperature can have no epistemic content.

The three fundamental claims of the talk,

1. that a theory is best characterized by its epistemic content,
2. that the epistemic content consists of theoretical and practical components that are not cleanly separable,
3. and that one cannot represent a theory as a theory about the world without knowing how in practice to be able to schematize the observer in theoretical models

are, for me, themselves not cleanly separable, but hang together.

The miracle of science is that theory and experiment are consonant with each other; the necessity of science is that they are inextricably so—not, however, as equals. Theory plays Boswell to the subtle and tragic clown of experiment's Johnson.

Stein, Howard. 1994. "Some Reflections on the Structure of Our Knowledge in Physics". In *Logic, Metholodogy and Philosophy of Science* IX, edited by D. Prawitz, B. Skyrms, and D. Westerståhl, 633–655. Proceedings of the Ninth International Congress of Logic, Methodology and Philosophy of Science. New York: Elsevier Science B.V.