

## *A Matter of Phronesis: Experiment and Virtue in Physics, a Case Study*

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This paper presents an integrated historical and philosophical approach to ongoing scientific controversies: it explores the dialogue between theory and experiment in contemporary physics, through the history of Condensed Matter physics (CMP), and offers an analysis of it via Virtue Epistemology (VE).

A common thread of the arguments made here is the view that the study of science as it is practiced by its community is of fundamental importance for philosophy of science. In particular, the input of experimentation and experimental practice, I argue, is epistemically crucial.

As a case study, I focus on the balkanization of the theory community in High Temperature Superconductivity (HTS) and explore the many roles experimental evidence has been playing in the battles there. In fact, in the 25 years that followed the discovery of HTS, the Condensed Matter Physics (CMP) community has experienced serious difficulties in trying to reach a consensus on a 'final' theory. These difficulties, I maintain, underlie controversial and often ambiguous theories of evidence, feeding dissent. The case study explores some of the reasons for such dissent, starting from testimonies that I collected through personal interviews with HTS physicists, ranging among top Nobel laureates and young researchers.

The paper focuses on the way experiments actively contribute to the formulation of theories. I claim that there is a tension between methods and aims of different scientific traditions, as they implement that contribution from experiments. Such tension is shown through the discussion of some episodes from the history of Superconductivity and CMP research, following the debates and works of R. Feynman, P.W. Anderson, B. Mathias and J. Bardeen. In particular, the different traditions are shown to offer not just and not necessarily different implicit epistemic virtues as relevant but most importantly different preferences among the shared ones.

After introducing the controversy in CMP and the debates that animated its history, I will present them from a VE standpoint. Under this light, we see that epistemic virtues form very complex relationships, where the importance of some virtues is at best denied "locally" in relation to another's, while some get to be pre-requisite or conditions for another.

Take these two aims, which a virtuous theory of a complex phenomenon should ideally reach:

- A) To give the most accurate and complete description of the phenomena.
- B) To explain the phenomena in a way that is consistent with accepted/acceptable principles and theories.

A theory in a non-ideal case will only be able to achieve these aims partially, leaving room for future improvements, even for the most successful theories.

This being the case, we will find that when we need to evaluate theories or models (or practices) we can try to assess how well they fit the two different desiderata; we would then evaluate the merits of different candidate theories differently according to the different weights that we may assign to the implementation of each of the two aims. My case shows a spectrum of preferences in this regard in scientific practice.

In Anderson's view, for example, a theory which suffers to some extent under the weight of experimental evidence is still saved by its consistency with first principles, which I discuss suggests not only how important internal logical coherence is for Anderson but also the extent to which empirical adequacy and predictive power are seen by him as secondary. He maintained that the desideratum of empirical adequacy should only be the focus of the last phase of development of a theory.

This, far from being a trivial matter of prioritizing, is justified on the basis that finding the supposedly unique way to account for the phenomena consistently with first principles represents for him "the end of the story", after which quantitative agreement will inevitably follow. For Matthias, on the other side of the spectrum, a model that lacks internal consistency and a first-principle derivation has a good chance of leading to the true mechanism for the phenomena as long as it seems to be empirically adequate, and it is then from there that a more principled account can be built, if we need or want one (though for purely practical purposes we may not).

Developing this and other examples I will then argue that the difference between the scientists presented is in their degree of confidence that starting from, on the one hand, first principles or, on the other hand, the phenomena and their description, will lead them to the desired solution.

This is then not merely a difference of goals, but a difference in conceiving the connection between them. It is not just a matter of preferring a complete description over a principled explanation. It is a matter of the scientist's judgment as to beliefs and confidence over which one is the best starting point from which to achieve the other. That is, it depicts different virtues of *phronesis*, or practical wisdom, in light of conflicting or complex desiderata or virtues.

The differences highlighted by this VE approach do not just matter to methodology but in fact underlie different conceptions of what it means to formulate a theory and to succeed in problem solving.

From the point of view of a rational a posteriori reconstruction of the contentious issues between theories, this issue of contention on methodology, and criteria for consensus, may be invisible. By looking at scientific practice (in its historical evolution) and at the dialogue between the two different traditions in problem solving in physics, the issue becomes visible, open to interpretation, and able to contribute to our models of scientific progress and to the discussion on scientific consensus.