DOUBLE STANDARDS, MULTIPLE DISSENTERS:

EVIDENCE, THEORIES, AND THE SUPERCONDUCTIVITY CASE

EXTENDED ABSTRACT FOR &HPS 2

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This paper looks at the history of High Temperature Superconductivity (HTS), one of the most fascinating, debated and controversial areas of contemporary scientific research. This case study is used to explore the role of evidence in the stages of theory formulation in the run for a 'final' theory.

Superconductivity is a peculiar phenomenon observed in certain materials when they are cooled to below their superconducting transition temperature. Superconductors are characterized by the complete absence of electrical resistance and the repulsion of external magnetic fields.

Conventional or Low Temperature Superconductors (LTS) were first observed a century ago and later explained through the Bardeen-Cooper-Schrieffer (BCS) theory. BCS theory was formulated in the 1950s and won the Nobel Prize in 1972, becoming not only the leading theory in Condensed Matter Physics but also one of the most compelling successes of theoretical physics.

BCS derived a formula for the temperature at which a superconducting material makes a transition to the superconducting state (Tc) and from that an approximate upper limit to the transition temperature of around 30 K. In 1986 new types of materials broke down that wall and showed unusually high transition temperatures (up to a recently patent pending superconductor which exhibits an extraordinary Tc of 200 K!). Ever since the Condensed Matter Physics community has been struggling with the problem of how superconductivity arises in certain materials at higher temperatures than that of conventional superconductors.

Most scientists agree that the electrons still pair in the new materials, as they do in BCS theory, but disagree on just how that mechanism is mediated. Despite much intensive research in the 25 years that followed the discovery of high temperature superconductors and many promising leads, an answer to this question has so far eluded scientists. Tens of theories have been offered so far and the community is rife with dissent and disagreement. To this date, even the most popular and promising candidate theories are seen as unsatisfactory. Each, however, is hotly defended by its own advocates and attacked by the advocates of opponent theories.

Traditionally empirical evidence, and especially in contemporary physics, experimental evidence, is supposed to play an important role in adjudicating these kinds of disputes. That is certainly a norm that is widely accepted in the HTS physics community, where it is commonly believed that “we need to fit ‘all’ of what is seen as the relevant data”. (Scalapino, one of the most important theoretical physicists in HTS)

I will show not only how the experiments have the power of testing whether the approximations proposed by the different theories hold and actually fit with what we observe, but also how they can be an active guidance in formulating different approximations or in isolating different sets of factors or mechanisms that could explain the phenomenon.

For this reason the increasing power of experimental techniques (a progress which has been particularly impressive in the last ten years) has greatly pushed the theoretical developments.

Despite the fact that the different physics groups supporting different theoretical approaches all agree on the importance of accounting for all the relevant data, this has done little to mitigate the fierce disputes. I shall argue that this is no surprise since turns out that they have quite different views about how data are relevant and what they are relevant to. It is typical for one group to attack and discard an opponent's theory T in the light of claimed evidence against it (since then T obviously does not fit '*all*' the data). But the opponent often does not accept this judgement, on the grounds either that those data are flawed or that the data do not after all count against T: it may only look to do so given mistaken assumptions made by the first group, or it may be irrelevant given the fact that one's own set of experiments suggest a different and more favourable view. This looks to be a double standard – this is just the issue I explore in this paper. I shall argue that physicists engaged in the debates in HTS seem to make *different assessments of the evidence X as robust enough to be used against T and of evidence X' as evidently weak when used against T'. Because the standards for such different assessments is left unspecified and unexplored, the field remains open to a great deal of subjective exercise of unspecified preferences and strictly unjustified beliefs.*

One of the principal characters in the HTS controversy, Phil Anderson, cuts this Gordian knot in his own way when he asserts that "[*A theory*] *which* is for example consistent with previous accepted theories [or promising for principled arguments or beliefs] but *disagrees with experiments is often not wrong, for we often find that experimental results change, and then, eventually later, the results fit the theory*". If we take this radical alternative and we follow such line to evaluate theories, then we need to clearly reset the bar for experimental evidence and admit to bring it back to a secondary role (one of corroborating theories only after they are sound and safe built from first principles). At the same time, we could no longer appeal to some convenient evidence to push for our theory T and suppress, discard or devalue an opponent's theory T'.

I will present examples and cases from the scientific literature to illustrate these double standards in the HTS practice. I have also personally interviewed many HTS physicists, from the top Nobel Laureates to the young researchers, and extracted some qualitative results from those conversations.

Until this ambiguity in the adjudication of evidence re theories is clarified, keeping such vocal judgement of adversaries' hypothesis with double standards for evidence is going to inevitably foster destructive dissent. "There are a lot of different materials, and room enough for everyone!" says Scalapino, and I join his call for a more tolerant pluralist approach to bring benefits to the field.