

## Dirac's "fine-tuning problem": A constructive use of anachronism?

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Recent philosophical discussions of cosmology have made much of the "fine-tuning" of parameters in our currently most fundamental theories. Roughly, a parameter is fine-tuned when the range of values of that parameter that are compatible with some observed feature of the universe is quite small relative to the range of values that are, in some sense, possible. Some have argued that such instances of fine-tuning provide evidence for the creation of the universe by an intelligent being (Craig 2003, Swinburne 2004), claiming that no other explanations of such fine-tuning are plausible. Others think the situation calls for some variety of "anthropic" explanation (Vilenkin 2006). Such claims might be undermined should it be found that physicists have a history of solving fine-tuning problems not by invoking divine providence or the anthropic principle, but through physical theorizing and experiment.

In this paper I wish to consider whether there might be episodes in the history of physics in which fine-tuning problems have been addressed through the development and experimental testing of physical theories. A candidate for such an episode can be found in the development of quantum electrodynamics (QED) in the 1930s. Closer scrutiny of that episode will reveal that, although the problem encountered can be reconstructed as a fine-tuning problem, its conceptualization by the physicists who confronted it (Bohr, Heisenberg, Oppenheimer, Pauli, and Weisskopf, *inter alia*) was rather different. I will conclude by suggesting that their ways of thinking about their "fine-tuning" problem might offer some clues for how we might think differently about ours.

Such an argument requires a degree of what I shall call "constructive anachronism." Thus, while engaging in a historico-philosophical argument, I will also consider both the dangers and advantages of various forms of anachronism in the pursuit of a philosophical argument that draws upon historical resources.

The idea of a 1930s fine-tuning problem has been suggested by the theoretical physicist Hitoshi Murayama. He characterizes the divergence of the self-energy of the electron in Dirac's theory of the electron as a fine-tuning problem, while pursuing an analogy between the chiral symmetry of Dirac's theory (Dirac 1928, 1930) and the supersymmetry of potential successors to the Standard Model (Murayama 1994, 2004).

In short, Murayama treats the rest mass of the electron in Dirac's theory as the sum of two contributions, which required fine tuning a divergently large and negative "bare" or "mechanical" mass contribution to balance the divergent self-energy contribution, yielding the small observed value. Moreover, he regards the first steps toward a solution to this problem as having been provided (in work by Victor Weisskopf, with a correction by Wendell Furry (Weisskopf 1934b,a, 1983)) by the chiral (matter/anti-matter) symmetry of Dirac's equation. (SUSY, he argues, addresses a similar fine-tuning problem — the gauge hierarchy problem — by employing an analogous symmetry.)

Murayama's argument exemplifies a phenomenon discussed some years back by Thomas Nickles (1992): he rewrites the history of science in "Whig" fashion to contextualize and guide the interpretation of current research. Physicists working during the early history of QED did not depict the self-energy problem for electrons as a fine-tuning problem, nor did they greatly emphasize the role of positive electrons in solving the problem. Indeed, rather than thinking that the "bare mass" contribution needed

to be “tuned” to a large negative number, Weisskopf, Pauli, and others tended not to present the rest mass as the sum of these two terms at all. Even when the rest mass was thus regarded (as it was much later in Weisskopf 1949), it was not discussed as a situation calling for fine tuning, but rather for some other theoretical revision.

Nonetheless, Murayama’s anachronism can be put to good use: although the divergences in early QED were not at the time analyzed as instances of fine-tuning, they exhibit a genuine structural similarity with such problems. What makes Murayama’s anachronism scientifically reasonable is, I argue, a similarity in the logic of the self-energy problem and the fine-tuning problems in current cosmology. The fact that such an interpretation of the problem was not shared by those who worked on the problem at the time suggests that their alternative conceptions of the problem might be fruitfully applied to such current fine-tuning problems as that regarding the cosmological constant. However, to pursue that route requires first a clear understanding of just how the self-energy problem was regarded in the 1930s. This historical task, drawing upon published work (Miller 1994) including Pauli’s correspondence (Pauli 1985) as well as research I have conducted in Weisskopf’s unpublished papers, will constitute the main focus of this paper, but I will also sketch the way in which the results of the historical inquiry might recast our philosophical perspectives on fine-tuning problems in current cosmology.

Nickles argued that anachronistic, “Whig” history has a role to play in science, so long as we keep clearly in mind the distinct aims of the scientist who thus appropriates the history of her discipline to her own argumentative aims. Likewise, I claim that a certain degree of anachronism is acceptable in philosophy of science so long as it is not confused with real history, and the distinction between philosophical and historical aims is kept clearly in mind. Nonetheless, I do not claim that the two cases are entirely alike. In particular, philosophers of science, because of the proximity of their discipline to history of science, bear a greater responsibility to be explicit about exactly which elements in their discussions of historical episodes contain projections of contemporary philosophical concerns onto historical episodes that did not share those concerns, and about just how their anachronisms would have to be corrected to get a clearer and more properly historical understanding of the developments discussed.

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