On an alleged fine-tuning Problem in Dirac's Electron Theory and its partial Solution by Weisskopf

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Abstract:

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. The latter claim might be undermined should it be found that physicists have a history of solving fine-tuning problems not by invoking divine providence, but through physical theorizing and experiment.

In the course of an analogy between the chiral symmetry of Dirac's theory of the electron (Dirac 1928, 1930) and the supersymmetry of potential successors to the Standard Model, the theoretical physicist Hitoshi Murayama has discussed the divergence of the self-energy of the electron in Dirac's theory as an example of just such a fine-tuning problem (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,11983)) 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.)

Contrary to Murayama's anachronistic discussion (see Nickles 1992), papers written 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 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. Two lines of inquiry emerge from this similarity. First, does Murayama's "historical" example provide a reason for thinking that the fine-tuning problems in present theory can be solved through physical theorizing rather than by invoking "design"? Second (the focus of the present paper), on what premises does Weisskopf's chiral symmetry "solution" of the self-energy fine-tuning problem depend? And what could be concluded about those premises from this solution?

To address this latter question, I will employ both philosophical analysis and a more properly historical perspective. The first step is a closer study of Weisskopf's paper and the context in which it was written (see also Miller 1994). Although Weisskopf claims that he approaches the self-energy problem using Dirac's "L □ochertheorie," it is not at all apparent that the hole interpretation of Dirac's formalism plays any essential role in his argument, which was written while he was serving as Pauli's assistant, at a time when Pauli was expressing considerable "disgust" with Dirac's hole theory (Rueger 1992). Indeed, Weisskopf collaborated with Pauli on a hole-free theory including positrons which Pauli referred to as the "anti-Dirac paper" (Weisskopf 1989, 163); the theory was acknowledged from the outset not to be realistic, but Pauli noted that it made him happy in the paper "once again to blame my old enemy – the Dirac theory of the spinning electron" (Pauli 1985, letter to Heisenberg, 14 June 1934). This aspect of the paper will draw upon published papers including letters in the Pauli correspondence in which Pauli, Heisenberg, and Weisskopf exchange their views regarding Dirac's theory (Pauli 1985). I will also make use of research I have conducted in Weisskopf's unpublished papers, which have just recently been made available at MIT.

Though not the focus of the present paper, it is intended that this close analysis of Weisskopf's work, as well as a broader historical survey of the evidential grounding of the positron through experimentation and argumentation will feed into a philosophical analysis and contrast with the deployment of "fine-tuning arguments" in current philosophical and physical discussions.