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Squaring the circle: Gleb Wataghin and the prehistory of quantum gravity

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ABSTRACT

The early history of the attempts to unify quantum theory with the general theory of relativity is depicted through the work of the Italian physicist Gleb Wataghin, who, in the context of quantum electrodynamics, has anticipated some of the ideas that the quantum gravity community is entertaining today.

1. Introduction

The problem of quantizing gravity, at least in its scientific facet, is one of finding a consistent mathematical framework that could yield predictions for phenomena that involve both quantum field theoretic and gravitational effects. Historical studies of this problem are almost non-existent; an understandable fact given that contrary to quantum field theory, whose success stories are well known, the "hit or miss" approach to the problem of quantizing gravity has resulted in many contenders, each with its own conceptual difficulties. Consequently, there is currently no such agreed upon quantum theory of gravity, and so it isn't surprising that a coherent historical account thereof is still lacking.

From the perspective of the history of ideas, however, one could still point at several key insights and strategies that have emerged already in the 1930s in the context of unifying quantum theory and the *special* theory of relativity, namely, quantum electrodynamics (QED), and that have made their way through the 1940s and the 1950s into contemporary discussions on possible solutions to this problem. In the quantum gravity community these earlier insights and strategies are commonly associated with several prominent figures such as Heisenberg, Born, Snyder, De Witt, and Wheeler, whose careers and reputations supersede by far their contributions to this highly speculative domain. The role of other less famous physicists in the development of these ideas is becoming more apparent only recently. Worth mentioning in this context is the Russian Matvei Bronstein, whose untimely death at a Leningrad prison in 1938 put an end to a promising career (Gorelik, 1992). The paper here presented illuminates another such figure, the Ukrainian-born Italian Gleb Wataghin, whose work, contrary to Bronstein's, is still unknown to most of contemporary quantum gravity theorists.

The purpose of this paper is twofold. First, it aims to highlight several key problems that are discussed today within the quantum gravity community, and to give support to the claim that their origins lie in the operationalist and relationalist quests for minimal length in the context of the development of QED. Second, it puts forward a conjecture about Gleb Wataghin's role in the development of these operationalist and relationalist ideas, and attempts to justify it with evidence from Wataghin's work.

Admittedly, from a historiographical perspective the conjecture here presented (of Wataghin's anticipation of some of the quantum gravity ideas) is hard to prove, as it requires archival sources

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that could give us hints to Wataghin's thoughts. Unfortunately, I haven't yet been able to locate too many of such sources. With the exception of transcripts of three interviews held with Wataghin in 1975–1976, the paper presented here relies almost entirely on Wataghin's published work. Since the latter is extremely short and sometimes even cryptic, one is thus left with the danger of projecting current ideas onto the past. And yet, with these caveats in mind, I believe that the work which is discussed below, along with the aforementioned interviews, still allow me to point at interesting connections that exist between contemporary quantum gravity research and the problems that occupied Wataghin in the 1930s.

The paper is structured as follows. In Section 2 I present a brief scientific biography of Gleb Wataghin. In Section 3 I focus on seven papers in which Wataghin expresses ideas that later would become popular among his contemporaries, and that ultimately would be rediscovered by quantum gravity theorists. In doing so I also mention several other key figures who worked in the 1930s on similar ideas, and trace the historical trajectories of these ideas through the 1940s and the 1950s up until the beginning of the 21st century. Section 4 concludes.

2. Gleb Wataghin

Gleb Wataghin (1899–1986) was born in Birsula (Ukraine) to a well to do family of jewish origins, and did all his secondary studies in Russia. His father was an officer and engineer in the Russian Imperial Train System. In 1919, after the revolution, the whole family migrated to Italy and settled in Turin. There Wataghin did translations from Russian to Esperanto, and taught Latin and mathematics. In 1922 he obtained a doctorate in physics from the University of Turin, and in 1924 he was hired as an assistant by the polytechnic school of that university. Five years later he received from the Italian Ministry of Education the libera docenza in theoretical physics to teach advanced physics.

In 1927 Wataghin attended the international physics conference commemorating Volta's centenary, held in Como, where he became acquainted with the best-known physicists of his time. The first paper he published on minimal length in 1930 in the *Zeitschrift für Physik* (Wataghin, 1930b) was discussed at the Solvay conference of that year and led to an exchange of letters with Enrico Fermi (Wataghin, 1975, p. 3). In 1931 Wataghin began his studies on cosmic rays. It is in this context that he would present his idea of the relativistic high momentum cutoff for the first time. In 1933 Wataghin traveled through Europe on a trip that would shape his life as a scientist, spending a few months in contact with Lord Rutherford in Cambridge, a few weeks in Copenhagen with Bohr, and a short time in Leipzig, where Heisenberg worked. His memories from this trip show the extent of the cordiality with which he was received in the small elite of scientists, despite his anonymity (Schwartzman, 1991; Wataghin, 1975).[1]

In 1934 Enrico Fermi was approached by the Brazilian mathematician Teodoro Ramos, who was commissioned by the governor of the state of Sao Paulo to head the recruitment committee for the newly formed Faculdade de Filosofia, Ciencias e Letras da Universidade de Sao Paulo. Fermi indicated Wataghin as a possible candidate, along with the young mathematician Luigi Fantappié. Wataghin was reluctant at first, but after a personal meeting with Ramos at a fancy restaurant in Rome he conceded. His two papers on the relativistic cutoff that would spark the research program of nonlocal field theories were published before and after his relocation.

With the clarity of hindsight, Ramos' choice was more than fortunate. While not belonging to Europe's first rank of physicists, Wataghin was close enough to understand the work of the leading names, know them personally, and could easily identify suitable research topics for himself and his students. Indeed, until today he is regarded in Brazil as the founder of physics research in the country (see, e.g., Salmeron, 2002). Between 1934 and 1942 he developed two research lines: one in theoretical particle physics and the other on cosmic rays. His prize student was Mário Schönberg, who would later become one of Brazil's most famous theoretical physicists.

Wataghin returned to Italy only in 1949, to become director of the institute of physics at the University of Turin. He continued to work on cosmic rays, as well as to develop his interest in nonlocal field theories. In 1966 the University of Campinas (Sao Paulo) honored Wataghin by naming its newly established institute of physics after him.

3. A trailblazer in quantum gravity?

Wataghin's ideas that anticipated several major themes in current scholarship on quantum gravity are best expressed in several papers he published between 1930 and 1938, where he discusses the notion of absolute uncertainty as designating a lower bound on spatial resolution, the notion of a relativistic upper bound (cutoff) on momentum transfer in particle collisions, and the convergence of these two insights into the idea of a curved momentum space as a basis for a theory of quantum gravity. The unifying thread in all these ideas is the notion of minimal length.

3.1. Ideas about the minimal length in the context of QED

The notion of minimal length entered into modern physics around the 1930s, with the attempts to tame the singularities and divergences that plagued field theories, both classical and quantum (for a detailed historical and philosophical account see Hagar, 2014). Motivated by contemporary data from particle physics, as well as by the theoretical lessons from classical and quantum electrodynamics, most physicists believed that the minimal length, if it existed, must be of the order of the electron radius, namely, $\sim 10^{-13}$ cm.

Those were years of turmoil and flux in theoretical physics. From the experimental perspective the landscape of particle physics was constantly being shaped as more and more data was being accumulated on cosmic rays. From the theoretical perspective the divergence of quantities such as the self-energy of the electron and the vacuum polarization raised questions about the internal consistency of the recently conceived QED.

Heisenberg and Pauli (1929) published two long papers where they developed a theory of the interaction of light and matter by quantizing Maxwell's equations of the electromagnetic field. One of the difficulties that emerged from their work was the problem of the self-energy of the electron. At first they discarded it as an irrelevant additive infinite constant, but in the second paper they admitted that such a move restricts the domain of applicability of the theory. Despite this shortcoming, Heisenberg and Pauli were confident that *any* future correct theory of field quantization, even quantization of the gravitational field, "…should be feasible without any new difficulties by means of a formalism completely analogous to the one used here" (Miller, 1994, p. 34, footnote 14). We know today how difficult this task has turned out to be.

Soon after, the presence of infinities was confirmed in calculations of the electromagnetic self-energy of a bound electron by

[1] Wataghin recalls that he was invited to Rutherford's house in Cambridge and met Dirac whom he befriended. In Copenhagen he met Bohr, and on the latter's invitation presented his ideas to Heitler, Heisenberg, and Pauli. In Leipzig Wataghin met also Jordan, Debye, Max Born, and even Ettore Majorana.