THE THIRD WAY TO QUANTUM MECHANICS IS THE FORGOTTEN FIRST

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Before the discovery of quantum mechanics by Heisenberg and Schrödinger, Gregor Wentzel had anticipated the concepts of Feynman's path integrals.

In the paper by Gregor Wentzel *Zur Quantenoptik*[1,2] (On quantum optics, February 1924) you find

- the concept of the value of a virtual path being the deviation of the action from its extremum,
- the interpretation of this value as a phase,
- the concept of interference of paths that are not subject to the canonical equations,
- the interpretation of the result of the interference as the probability amplitude of some transition.

Hence, Wentzel anticipated already in 1924 the physics of Feynman's path integrals.[3,4]

How to obtain interference and dispersion with a flow of particles was a topical subject at that time. After Einstein's conjecture of light quanta, the particle picture of light (*Nadelstrahlung*) had passed the test of aberration phenomena through relativity theory, but interference was still to be explained. Wentzel's aim was to understand interference as the result of underlying quantum-statistical laws. At that time, the Bohr-Sommerfeld condition was generally accepted, while the Wiener functional integration was still unknown to physicists. The Bohr-Sommerfeld condition seemed to prohibit the interaction of an atom with light quanta of frequencies different from the transition frequencies. Dispersion however showed that this could

not be the case. Wentzel tried to describe light quanta by the disturbance produced in the atoms, which he called non-mechanical. In fact, he assumed emission, absorption and propagation of light quanta to be associated with virtual motions not subjected to the canonical equations. The contribution of the individual virtual motions of the atoms to the statistical behaviour of light quanta was measured by the action integral. Wentzel introduced the phase proportional to this action, and he assumed the transition probability to be the square modulus of a complex amplitude obtained by the superposition of individual amplitudes built with that phase for every virtual path. This means that Wentzel invented the concept of interference of virtual paths, and the concept of the transition probability in this context.

As we understand it, Wentzel's paper has been forgotten because

- Wentzel aimed at optics, although his formulae are mechanics,
- the application of his theory to dispersion failed because of an approximation that a posteriori turned out to be not appropriate.

In the transcript of an interview to G. Wentzel (3.-5.2.1964, Chicago), T.S. Kuhn wrote:[5] *About the "Quantenoptik" paper Wentzel has very little to say, nor can he say much about the two papers which are associated with it, one on Bremsstrahlung and the other on dispersion. He does remember that almost no one paid any attention whatsoever to this work, though he is quite clear that it was the only attempt at a fundamental treatment of the difficulties which he himself attempted during this period.*

Acknowledgements

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References

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