



# **Life of Pauli and his Role in the History of Science**

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# Wolfgang Pauli

- “He tried first of all to be inspired by the experiments and to see in a kind of intuitive way how things are connected, and at the same time he tried to rationalize his intuitions and to find a rigorous mathematical scheme so that he really could prove everything what he said. . . Pauli has through his whole life published much less than he could have published if he had abandoned one of these two postulates.” (Heisenberg)





# A brief biography

1900: born in Vienna (godfather: Ernst Mach)

1918: first paper on general relativity

1921: PhD in Munich under Sommerfeld

1921: Review paper on relativity theory

1921-22: Göttingen (assistant of Born)

1922-23: Copenhagen

1923-28: Hamburg (assistant of Lenz)

1928-40: Professor at ETH Zürich

1931: breakdown, connection to Jung

1931: Lorentz Medal

1940: Professor at Princeton

1945: Nobel Prize (nominated by Einstein)

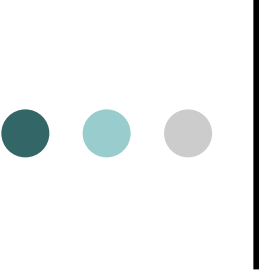
1945: return to Zürich

1958: dies in Zürich



# Background physics

- Symmetry
  - Spin, 1924
  - Neutrino, 1930
  - Spin statistic theorem, 1940
  - CPT theorem, 1956
- Complementarity
  - Synchronicity
  - Physis and psyche
  - Unus mundus



# Spin, 1924

- 1922-23: Copenhagen — anomalous Zeeman effect
- Spin, 1924
  - two-valued degree of freedom: fourth quantum number
  - Uhlenbeck, Goudsmit, 1925: spin
  - Pauli: “Once a new system is conceptually settled, it will be vividly imaginable (‘anschaulich’) as well”
- Exclusion principle, 1925: no two identical fermions may occupy the same quantum state simultaneously
- Quantum state of an elementary system has to transform according to an irreducible representation of the permutation group
  - Nobel Prize, 1945: for his “decisive contribution through his discovery in 1925 of a new law of Nature, the exclusion principle or Pauli principle”



# Quantum mechanics, 1925

- “Energy and momentum values of stationary states are something much more real than ‘orbits’”  
→ matrix mechanics, 1925
- “One can look at the world either with the p-eye or one can look at it with the q-eye, but if you will simultaneously open both eyes, you get lost”  
→ uncertainty principle, 1927



# Neutrino, 1930

- Before 1932: proton, electron, photon
- $\beta$ -decay
  - Bohr: violation of energy conservation?
  - Pauli: “I am myself fairly convinced . . . that Bohr with his corresponding deliberations concerning a violation of energy conservation is *entirely* on the *wrong* track [ganz falsch]!”
- conservation of energy and momentum → neutrino (term coined by Fermi)
- Cowan, Reines, 1956: experimental test
  - “Everything comes to him who knows how to wait”

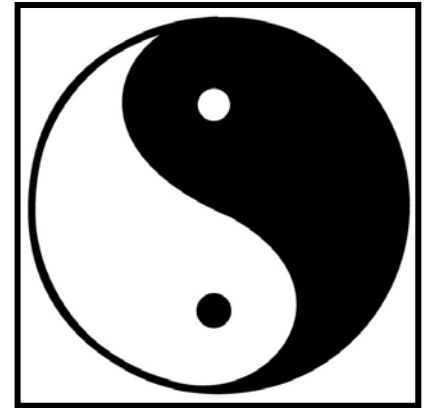


# Spin statistic theorem, 1940

- Quantization of
  - particles with integer spin: Bose-Einstein statistics
  - particles with half spin: Fermi-Dirac statistics
- “The connection between spin and statistics is one of the most important applications of the special relativity theory”



# CPT theorem, 1954



- C: charge, P: parity, T: time
- CPT symmetry: fundamental symmetry of physical laws under inversion of charge, parity and time
  - Violation of the parity symmetry in  $\beta$ -decay, 1956
  - Violation of the charge-parity symmetry in kaon decay, 1964
- CPT symmetry  $\Leftrightarrow$  Lorentz invariance



# Complementarity, 1927

- Heisenberg, 1927: uncertainty principle
- Bohr: Copenhagen interpretation
  - correspondence principle
  - statistical interpretation
  - reduction of the wave packet
  - complementarity
- Kant: object = sensorial content + causal space-time description
- Bohr: the preconditions of objective knowledge are the classical concepts:
  - “space,” “time,” “causation,” “continuity”
  - Conditions of unambiguous and meaningful communication
  - Classical physics: refinement of the preconditions of human knowledge



# Complementarity, 1927

- Complementarity: mutually incompatible and jointly necessary descriptions of reality (context-dependent Boolean descriptions of a non-Boolean structure)
  - wave-particle duality
  - kinematic (space-time) vs. dynamic (causal) descriptions
  - EPR argument, 1935: “phenomenon”: a complete description of the entire experimental arrangement



# The “detached observer”

- Bohr, 1955: “detached observer” — *subjectivity* can be eliminated
- Pauli: “Dear Bohr, ... under your great influence it was indeed getting more and more difficult for me to find something on which I have a different opinion than you. To a certain extent I am therefore glad, that eventually I found something: the definition and the use of the expression ‘detached observer’ ...  
... I consider the unpredictable change of the state by a single observation — in spite of the objective character of the results of every observation and notwithstanding the statistical laws for the frequencies of repeated observation under equal conditions — to be an abandonment of the idea of the isolation (detachment) of the observer from the course of physical events outside himself.”



# Physis and psyche

- “It would be most satisfactory of all if physis and psyche could be seen as complementary aspects of the same reality”
- Analogy between field and unconscious
  - Problem of observation
  - Extension of causality: statistical law and synchronicity



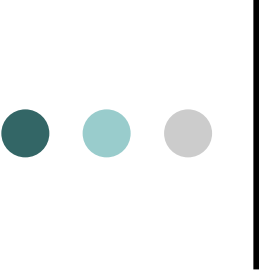
# Synchronicity

- Synchronicity: the simultaneous occurrence of two meaningfully but not causally connected events
- Synchronistic  $\neq$  simultaneous (Pauli: “Sinnkorrespondenzen”)
  - Jung: unique coincidences
  - Pauli: acausal statistical correspondence
- Synchronicity: meaning and goal-orientedness
  - Final causes are complementary to efficient causes
- Critiques of Neo-Darwinism
  - “We encounter here a third type of laws of nature which consists in corrections to chance fluctuations due to meaningful or purposeful coincidences of causally unconnected events.”



# Unus mundus

- What is reality?
  - “When he speaks of ‘reality’, the layman usually means something obvious and well known, whereas I think that the important and extremely difficult task of our time is to try to build up a fresh idea of reality.”
- Unus mundus
  - Synchronicity: A remnant of the unity of the archetypal reality of the unus mundus from which it emerges



# Irrepresentable structural element of the unconscious

- Jung: premordial image → archetype → psychoid
- Archetype: under matter and mind
- Pauli: “ordering principles, which are neutral in respect of the distinction psychical-physical, but which, in contrast with the concretistic psycho-physical unified language of ancient alchemy are ideal and abstract, that is, of their very nature irrepresentable (unanschaulich)”
  - Archetypes of mathematical concepts (e.g. continuum)





# Prescientific conditions of knowledge

- “It is obviously out of the question for modern man to revert to the archaistic point of view that paid the price of its unity and completeness by naive ignorance of nature. His strong desire for a greater unification of his world view, however, impels him to recognize the significance of the prescientific stage of knowledge for the development of scientific ideas.”



# Rationality and mysticism

- “In my opinion, it is a *narrow* path of truth (no matter whether scientific or other truth) which guides us through between the Scylla of a blue haze of mysticism and the Charybdis of a sterile rationalism. This path will always be full of traps, and one can fall to *both* sides.”

# References



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