When Pauli Met Jung – the Path from "Three" to "Four"

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What happened when the brilliant but troubled scientist, Wolfgang Pauli, met the great psychologist Carl Gustav Jung? Can Jung's analysis of Pauli's dreams shed further light on how Pauli made his greatest discovery: the exclusion principle? This dramatic story is the core of my forthcoming book (Miller 2008), to appear in 2008. Here I present part of the story based on the lecture I was privileged to present at Ascona.

The roots of Pauli's psychic life are intimately entwined with his scientific discoveries, beginning with the famous exclusion principle. In outline, Pauli's route to the discovery of the exclusion principle was as follows: In 1913, Niels Bohr proposed a theory of the atom based on an iconic image of it as a miniscule solar system. In Bohr's theory the electrons in an atom are restricted to occupy only certain orbits. Upon dropping from a higher to a lower orbit an electron emitted light of a certain frequency which could be detected in the laboratory as a spectral line.

Bohr's theory achieved a number of stunning successes. But it was beset by problems, such as: Why did not every electron in an atom drop into the atom's lowest orbit? By 1922, Bohr had managed to "guess" the correct distribution of electrons among the allowed orbits, but offered no details.

Another problem was that when an atom was placed between the pole faces of a magnet, many of its spectral lines split into more lines called multiplets. Certain of these lines defied explanation by Bohr's theory. Physicists referred to this situation as the "anomalous Zeeman effect", after the physicist Pieter Zeeman who discovered it. It baffled everyone, including the twenty-two-year-old child prodigy Pauli who obsessed over it. Eventually he decided to cease work on the problem altogether, but kept up with the burgeoning literature.

In December 1924, while on the faculty at the University of Hamburg, he had two brainwaves. First of all, he wondered what relativity theory had to say about the predominant model of an atom with one free electron, called an alkali atom. To some degree this mimicked the simple hydrogen atom with which Bohr's theory had had its greatest success. Scientists assumed that alkali atoms were made up of a closed inert core of electrons plus a single

free electron which was able to participate in chemical reactions. In order to explain the anomalous Zeeman effect Bohr suggested that the inert core could be distorted in one of two ways by some force which he defined only vaguely.

Pauli found that electrons in the core moved at velocities close to that of light. According to relativity this would cause changes in their mass which should influence the spacing between multiplets. But experimental data revealed nothing like this. Pauli concluded that the inert core model was wrong.

Then he recalled a recent paper by Edward F. Stoner, a physicist at the University of Leeds in England. The state of each electron in the Bohr theory of the atom was determined by three integer numbers, called quantum numbers. This seemed reasonable insofar as each electron moved in three dimensions. Through clever manipulation of these numbers, Stoner was able to relate the number of multiplets for the single electron plus the core in an alkali atom undergoing an anomalous Zeeman effect to the number of electrons that filled up an orbit.

Pauli realized how to interpret Stoner's result in a way that went beyond the anomalous Zeeman effect. He allocated to each electron in every atom the two-valuedness of the useless core. After a great deal of angst he did this by assigning to each electron a fourth quantum number with the value 1/2, soon to be associated with the spin of the electron. The result was that orbits filled up according to the rule that no two electrons in an atom have the same *four* quantum numbers. This is Pauli's exclusion principle. It explains why Bohr's "guess" worked for the atomic structure of atoms. Even more, it explains the structure of the periodic table of the chemical elements. Soon scientists found that Pauli's exclusion principle played a role in explaining why metals are hard and how certain stars die.

But many physicists were mystified by it. Where did the exclusion principle come from ? Could it be derived from Bohr's theory ? Pauli concluded the most important paper he ever wrote with the statement that the true meaning of his discovery would not be clarified until a deeper understanding of the quantum theory was obtained.

In a nutshell, this was Pauli's scientific route to the exclusion principle. Informative as it is, it is not the whole story. I would like to understand his thought processes and examine whether his unconventional life outside physics had anything to do with his creative thinking. At the core of Pauli's discovery was the expansion of the quantum numbers needed to define the state of an electron in an atom from three to four. Pauli could not put the feelings of angst it took to make this breakthrough out of his mind. Although Pauli compartmentalized his mental activity, might it have been that the watertight compartments of his mind broke down during his creative outburst of 1924 ?

One contributing factor in this respect was his secret nocturnal life. While by day Pauli was a staid Germanic physics professor, by night he often frequented the Sankt Pauli, the notorious red light district in Hamburg. There he found the means to alleviate his personal anger and the strains put on his psyche by a life defined by his physics research which he considered a failure

due to his inability to solve the anomalous Zeeman effect. He dropped into the underworld of drugs, alcohol, prostitution and pornography.

In the fall of 1927 a calamitous event occurred in Pauli's personal life – the suicide of his mother to whom he was very close. His father, Wolfgang senior, ever the womanizer, had gone one step too far. He had left his wife for another woman, a humiliation too much for her to bear. The great compartmentalizer, Wolfgang junior, never discussed his mother's death with colleagues. Instead he buried himself ever-deeper into his research. Luckily, the following year, the call to a professorship at the ETH, in Zürich, arrived offering Pauli the opportunity for a fresh start. Although in stolid Zürich there was no Sankt Pauli his travels back to Hamburg and Berlin made up for it. Socially he was managing quite well amid a congenial group of young physicists.

In the spirit of his favorite philosopher Arthur Schopenhauer, Pauli had always dismissed marriage as a bourgeois institution. So colleagues were amazed when in December 1929 he announced that he was to marry a cabaret dancer called Käthe Deppner. He had met her some years earlier during one of his many jaunts into the fetid demi-monde of Berlin. Suffice it to say that it was a mismatch. The marriage lasted less than a year.

Meanwhile, Pauli's scientific creativity never flagged. One month after the divorce, in December 1930, Pauli suggested a new particle – the neutrino – in order to preserve the conservation law of energy in beta-decay. Today new particles are suggested on an almost daily basis. In those days it was an audacious move – were not the electron, proton and light quantum enough ? It was extraordinary that at a time of such enormous personal trauma Pauli should come up with a concept of such importance. His powers of compartmentalisation were indeed astounding.

Far from taking his divorce from Käthe Deppner in the witty, sardonic way in which he presented it to others, he had gone on a binge of drinking and parties and resumed his life of bar-room brawls, smoking and womanizing. Eventually his bitter quarrels with colleagues at the ETH came to the attention of the administration, putting his position in jeopardy despite his brilliant work. He seemed to be living two separate mental lives. To add to all this, his always vivid "dreams and visions" were seeping into his waking life (Jung, 1975, §1264-§1275). By the beginning of 1932 he had plummeted to a frightening low point. Despite his difficult relationship with of him, Pauli heeded his father's advice to consult the celebrated psychoanalyst Carl Gustav Jung who, at fifty-seven years of age, was at the height of his fame.

Unlike Freud, Jung was interested in aspects of the psyche that could not be attributed to an individual's personal development but to the deeper non-personal realms common to humankind – the collective unconscious, whose contents he called "archetypes". These are not inherited ideas, rather they are latent potentialities whose origins remain forever obscure because they reside in the mysterious realm of the collective unconscious about which we will never have direct knowledge (Jung, 1969, §718). Whereas the archetype

itself is not representable, its effects enable us to visualize it as an archetypal image, or symbol.

Archetypes are hard-wired into the mind and serve as organizing principles allowing us to construct knowledge from the potpourri of sensations bombarding us. They influence our thoughts, feelings and actions.

Before visiting Jung, Pauli decided to read up on his psychology. He carefully studied Jung's 1921 book *Psychological Types*, in which Jung established a vocabulary and framework for his "analytical psychology". On the basis of his clinical experience and vast knowledge of Eastern and Western religions, philosophy and literature, Jung offered a theory of the mind based on two opposing psychological types: introverts and extraverts. He fine-tuned these notions with four basic functions, which he called thinking, feeling, intuition and sensation. He separated the four functions into two groups of two: thinking and feeling, intuition and sensation.

Jung sized up Pauli immediately. He saw before him a brilliant young man whose thinking function far outweighed the feeling function, causing a severe neurosis. Pauli poured out his troubles to Jung (1968, §45; 1975, §1268). He told him about his anger, his loneliness, his drunken brawls and his problems with women.

Jung and Pauli met for a short interview in November 1932 and then eight months later began to meet as regularly as possible on Mondays at noon in Jung's home in Küsnacht, just outside Zürich. Pauli had already written up 355 dreams. By the time they concluded their sessions about a year later, he had added another 45. Jung was elated. "They contain the most marvellous series of archetypal images", he said in one of the many lectures he gave on Pauli's dreams.[1] Complying with Pauli's request, he never mentioned who the dreamer was.

Jung's method in analytic psychology was to identify a patient's dream images with those from alchemy, religion and myth taking into account the four psychological functions. A typical analytical session with Jung started with a patient telling him about a dream. From the bookshelves lining the walls of his immense library or treatment room, Jung would then take down an ancient book of alchemical images and choose an appropriate one to discuss. Thus did Jung analyze Pauli's dreams. Eventually Pauli began to draw mandalas, signalling his achieving a balanced psyche. This stage culminated in Pauli's "great vision – the vision of the world clock".

In Pauli's words:[2]

> "There is vertical and a horizontal circle, having a common centre. This is a world clock. It is supported by the black bird. The vertical circle is a blue disk with a white border divided into $4 \times 8 = 32$ partitions. A pointer rotates upon it. The horizontal circle consists of four colours. On it stand four little men with pendulums, and round about it is laid the ring that was

[1] Moreover, he drew them "without being told to do so", said Jung (1975, §403).
[2] See the quotation by Jung (1968, §307) and Jung (1958, §111).

once dark and is now golden (formerly carried by the children). The 'clock' has three rhythms or pulses:

1. The small pulse:	the pointer on the blue vertical disk advances by 1/32.
2. The middle pulse:	one complete revolution of the pointer. At the same time the horizontal circle advances by 1/32.
3. The great pulse:	32 middle pulses are equal to one complete revolution of the golden ring."

Pauli now finally understood why he had struggled with the transition from three to four when he postulated the extra quantum number that would explain the structure of the atom in Bohr's theory with the exclusion principle. At this point Pauli's personal struggle between the numbers three and four ceased, although at first sight this may not seem to be the case in Pauli's "great vision". After all, the pointer on the blue circle moves in three rhythms or pulses. However it intersects with a circle divided into four parts, divided up with four colors and inhabited by four grotesque dwarves, called Cabiri, chthonic gods, dating back to ancient Greece, whose role is to protect sailors – here they are guides into the unconscious. While the *trinity* is the pulse of the system, the thirty-two pulses result from the multiplication of 4×8.

Jung also points out that thirty-two is a special number in the Kabbalah, connoting wisdom (Jung, 1968, §313). It can be written as the sum of twenty-two (the number of letters in the Hebrew alphabet) and ten (the number of branches of the Sephirot tree). Jung (1958, §125) reads Pauli's dream as a vision of a three-fold rhythm interpenetrated by a *quaternity* "so that each is contained in the other", thereby completing the incomplete trinity.

In Jung's experience, he tells Pauli, the conscious mind could not have forced the concept of the quaternity on the unconscious. Rather there is some psychic element present which expresses itself through the quaternity – completeness of the individual. The quaternity is an archetypal symbol.

Jung's analysis drove home to Pauli why his struggle in going from three to four in his discovery of the exclusion principle had been so very difficult. Not only was Pauli grappling with physics; he struggled with his neurosis as well. In this instance, alchemy, as Jung folded it into his analytical psychology, provided insight into the creative moment.

In 1951 Pauli wrote to his close friend and former assistant Markus Fierz:[3]

> "My way to the Exclusion Principle had to do with the difficult transition from three to four, namely, with the necessity to ascribe to the electron a fourth degree of freedom (soon explained as 'spin') beyond the three translational ones – that was really the chief thing."

[3] Letter 1286 from Pauli to Fierz of October 3, 1951, published in Meyenn (1996).

Jung often spoke about the case of the young intellectual scientist as a glowing example of his own lifelong belief that alchemical symbols shed light on the "development of symbols of the self" – and, he may have added, of physics, too (e.g. Jung, 1968, §323).

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