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Wolfgang Pauli and Philosophy

By K. V. Laurikainen

1. Introduction

Since those physicists who created quantum mechanics have almost all passed away, the criticism of the *Copenhagen interpretation*—or the “orthodox interpretation”—of quantum mechanics has become more usual. The Copenhagen philosophy is accused, especially, of its *positivistic trend*, while its critics usually proclaim some form of *realism* as their philosophical attitude. Einstein’s realism is often mentioned as motivation.

Wolfgang Pauli was, because of his sharp criticism, the most feared champion of the Copenhagen school, until his unexpected death on 15 December 1958. In this lecture, I shall try to describe Pauli’s philosophical views a little more closely than they are generally known. I hope that a better knowledge of his opinions will reduce the criticism directed at him and at the Copenhagen philosophy.

First, however, some personal data. Wolfgang Pauli was born in Vienna in 1900, simultaneously—or perhaps one should say, synchronously—with

the quantum idea. His father was a medical doctor and later professor at the University of Vienna. He was a Jew, but turned to the Catholic religion which was also his wife's faith. Wolfgang Pauli was baptized in the Catholic church. His godfather was *Ernst Mach*, one of the most famous proponents of the positivistic philosophy. Pauli once remarked that, obviously, Mach's personality "imposed itself more than that of the Catholic cleric with the apparent result that I received an anti-metaphysical rather than a Catholic christening".

Ernst Mach certainly had a strong influence on his godchild, to whom he also recommended scientific literature. The school class was inspiring, too, and it has been called the "class of the geniuses". The results of the education he received during his school years were extremely good, in spite of the World War. At the age of 19 Wolfgang Pauli was given an exceptional task: to write a long encyclopaedia article about the theory of relativity¹. Einstein himself has praised this article with words of admiration². When Pauli was later asked how it was possible to write such a comprehensive article about relativity at the age of 19, he answered: «Ach, ich war ein Wunderkind!»

In addition to Ernst Mach, two other physicists had a strong influence upon Pauli's scientific development: *Arnold Sommerfeld* and *Niels Bohr*. Pauli studied for six semesters in Munich³ where Sommerfeld was his teacher in theoretical physics. Pauli obtained his Ph.D. diploma on 25 July 1921. Sommerfeld's enormous knowledge and skill in the mathematical methods of physics created in Pauli an almost Platonic belief in the divine origin of mathematical ideas and their importance in the comprehension of the structure of reality.

Niels Bohr met young Pauli in Göttingen⁴ where, in 1922, he gave a series of lectures on the foundations of atomic theory. Pauli was then Max Born's assistant in Göttingen. Bohr invited Pauli to Copenhagen for the academic year 1922–23⁴ and this was the beginning of their continuous collaboration which has been so important for the development of physics. Pauli's fellow student from Munich, *Werner Heisenberg*, was the third member of this triad which revolutionized our view of the physical world. In a letter to Fierz, Pauli describes Niels Bohr as *the Teacher (der Lehrer)*, with an underlined article⁵.

Pauli obtained a full professorship in 1928, at the ETH (Eidgenössische Technische Hochschule) in Zurich. This remained his permanent working place until his death, with the exception of some years in America during the war.

2. The Philosophy of the young Pauli

Even stronger than Mach's influence, in the direction of a positivistic philosophy, was perhaps that of Einstein. His criticism of the concepts of space and time in Newtonian physics was quite along the lines of Mach's positivism, because Einstein pointed out that "absolute space" and "absolute time" are strongly hypothetical concepts, having no clear basis in experiments.

Pauli's own first articles were written in this same positivistic spirit. In 1919 he criticized Hermann Weyl's theory of gravitation and electricity as follows⁶:

"We operate, in Weyl's theory, continually with a field strength within an electron. Physically this is, however, defined as a force acting on a probe particle, and since there are no probe particles smaller than the electron itself, the concept of a field strength in a mathematical point seems to be an empty fiction without any meaning. One should, I think, preferably introduce into physics only such concepts which are observable, in principle. Might we not be on a wrong path when applying continuum theory to a field within an electron?"

Pauli repeated this criticism at a meeting of the German Society of natural scientists and physicians, in 1920, and then he explicitly referred to Einstein's positivistic remarks, stating that "no reality may correspond to such an idea" as the "conception of the electric field strength within an electron"⁷.

When studying the development of atomic theory in the twenties, it is evident that it was Pauli who first began to speak of the impossibility of an exact kinematical description of electronic motion within an atom. In a long letter to Bohr on 12 December 1924 Pauli writes⁸:

"I believe that the energy and momentum values of stationary states are something much more real than the 'orbits'. It must be the aim (not yet achieved) to deduce these and other *physically real, observable properties of stationary states* [italics by KVL] from the (integer) quantum numbers and from the laws of quantum theory."

From the experimental difficulties burdening atomic physics at the beginning of the twenties, Pauli thus draws the conclusion that an exact space-time description of electronic motion is impossible and therefore the idea of

definite ‘orbits’ should be rejected. The remark is made in an explicitly positivistic spirit.

N. B. Pauli’s criticism is directed, all the time, against the uncritical use of the concepts of space and time—like Einstein’s criticism in 1905.

Heisenberg, who was then in Copenhagen, may have studied Pauli’s letter carefully, because six months later he wrote his first paper on quantum mechanics⁹. There he puts Pauli’s ideas into practice, presenting a theory of stationary states without any exact kinematical description of electronic motion. So began the blurring of the kinematical description of motion in atomic theory. Schrödinger tried to rescue the exact space-time description by using waves, but he had only a partial success, and the result was, in 1927, the *complementarity philosophy* of Bohr.

There are many other examples of Pauli’s influence on the development of atomic theory, especially in letters. The main trend in his remarks was that one should avoid the use of the space-time description to a greater extent than is absolutely necessary for the explanation of the experimental results. This is a positivistic trend, common for young Einstein and for young Pauli, and there is no doubt about its fruitful influence on the development of physics, both in the theory of relativity and in quantum theory.

3. The Philosophy of the mature Pauli

This emphasis on Pauli’s positivism was perhaps unnecessary, because everyone knows that Pauli was a positivist, and the Copenhagen school has been criticized just because of its too positivistic philosophy. In the rest of my talk I wish to describe Pauli’s thinking in his *mature* age, in the forties and the fifties. I shall now try to convince you that the mature *Pauli was not a positivist* and that *the Copenhagen philosophy in quantum theory is not bound to positivism*.

I would like to say that many critics of the “orthodox interpretation” of quantum mechanics are tilting at windmills. The reason is, probably, that Bohr, Heisenberg, and Pauli wrote essential articles in German and most of their letters were written in German. It is difficult to understand their philosophical attitudes without reading German documents. With respect to Pauli, I can certainly say that he was not hiding in any positivistic windmills. He went very far in the direction which the critics of the “orthodox interpretation” usually recommend to us. I mean that *Pauli was a*

*realist**, and he has done more work than, perhaps, anybody else to make it clear for himself what kind of reality we meet in the atomic world if we accept quantum mechanics in its present form.

I shall base my remarks on the correspondence between Pauli and Markus Fierz which I have studied especially from the point of view of philosophy and history of ideas. This correspondence was very intensive from 1947 on, and continued until Pauli's death. Fierz was then professor of theoretical physics in Basle. He met Pauli usually on Mondays at the seminar on theoretical physics in Zurich. However, Pauli and Fierz also wrote long letters to each other, often 5–10 pages written in small handwriting, sending sometimes even two letters on the same day.

I am quoting here from *Pauli's letters to Fierz from some early years* of this correspondence. I hope that these quotations already give an idea of some basic features of the philosophy of the mature Pauli. I hope especially that they give an impression of the enormous amount of work that Pauli did in order to understand the philosophical implications of quantum mechanics. This was most important for him, but he wished also, in the light of modern physics, to understand the history of ideas in a much more general sense, in order to understand what changes are now taking place in the scientific view of the world, i. e. in our *conception of reality*.

4. Pauli's letters to Fierz

4.1 *Excerpts from these letters, in the original language*

The quotations given here are from letters written during the years 1947–51. They are reproduced in their original form, in German. Only a very short description of the subject treated and some clarifying remarks are added in English. For the convenience of those readers for whom the German

* Professor Fierz has pointed out that Pauli did not classify himself under any "ism". Quotations in Section 4 also show that Pauli's "realism" does not correspond to this "ism" in any traditional sense. However, Pauli thought that it is a most important task of science today to try to find out a *new conception of reality*. Therefore, I think, Pauli must be called a "realist" although the conception of reality to which the word refers in his case is only slowly taking shape.

Because of the strong influence of positivism on modern philosophy, philosophers often avoid speaking of ontology. I think that a realism "à la Pauli" can have a very healthy impact on philosophy.

language would be an obstacle, a translation into English * is given below (Section 4.2), for the most essential parts of the quotations.

*Letter 1, 30 March 1947 (PC0092.039) ***

The role of space and time in microphysics.

«Ich erwarte immer mehr eine weitere Revolutionierung der Grundbegriffe in der Physik, wobei mir besonders die Weise, wie das Raum–Zeit-Kontinuum in ihr heute eingeführt ist, in zunehmendem Maße unbefriedigend erscheint. (Es ist natürlich genial, die Zeit nicht mehr zur Anordnung von Kausalreihen zu verwenden – wie einst im Mai –, sondern als Tummelplatz von Wahrscheinlichkeiten. Wenn man aber statt *«genial»* sagt *«dumm-dreist»*, ist es mindestens ebenso wahr. Es geschieht doch wirklich nur etwas bei einer Beobachtung, wobei auch – wie mich Bohr und Stern endgültig überzeugt haben – die Entropie notwendig zunimmt. *Zwischen* den Beobachtungen geschieht GAR NICHTS, *nur die Zeit* ist auf den mathematischen Papieren *«inzwischen»* irreversibel weitergelaufen!)

«Sie sehen, die Ferien haben gewirkt, und ich bin wenigstens im Stande, in markanter Weise zu formulieren, was mich bedrückt. Dieses Raum–Zeit-Kontinuum ist nun ein Nessushemd [1] geworden, das wir nicht mehr ausziehen können! (Sie könnten statt *«Nessushemd»* auch sagen *«Vorurteil»*, aber das wäre erstens zu harmlos und würde zweitens den Irrtum zu stark von der bloßen Vorstellung auf das Urteil verlegen.)»

Clarifying remarks

[1] Nessushemd (shirt of Nessus) refers to the Heracles myth.

Letter 2, 29 December 1947 (PC0092.044)

The importance of studying the concepts of space and time, before Newton.

«Inzwischen habe ich meinen Ausflug ins 17. Jahrhundert weiter fortgesetzt. Daß Newton Raum und Zeit quasi zur rechten Hand Gottes gesetzt hat u. zwar auf den leer gewordenen Platz des von ihm von dort vertriebenen Gottessohnes, ist eine Pikanterie der Geistesgeschichte, die

* Done at CERN by Mr. J. Nichols, of the Documentation Department.

** Numbers in parentheses refer to the Pauli Collection at CERN.

mir erst durch die Lektüre Ihres Newton-Vortrages bekannt geworden ist. Bekanntlich hat es dann einer ganz außerordentlichen geistigen Anstrengung bedurft, um Raum und Zeit aus diesem Olymp wieder herunterzuholen. Diese Arbeit wurde noch künstlich erschwert durch Kant's philosophischen Versuch, den Zugang an diesem Olymp für die menschliche Vernunft zu sperren. [1]

«Deshalb ist für mich die Zeit besonders interessant, wo Raum und Zeit *noch nicht* dort oben waren und zwar der Moment gerade *vor* dieser verhängnisvollen Operation. Daher mein Studium von Kepler. Ich habe C.A. Meier versprochen, im psychologischen Club einen Vortrag zu halten über «Den Einfluß archetypischer Vorstellungen auf die Bildung naturwissenschaftlicher Theorien bei Kepler». [2] Kepler benutzt das Wort «Archetypen» und auch «archetypisch» in einer Weise, die genügend ähnlich ist dem Gebrauch, den Jung von diesen Begriffen macht, so daß es nicht notwendig ist, einen speziellen Unterschied zu betonen. (Sie benützen wohl auch beide dieselben antiken Quellen.) Sodann glaube ich einen vielleicht nicht uninteressanten Zusammenhang aus Keplers Schriften nachweisen zu können zwischen seinem sphärischen Trinitäts-symbol, und seinem leidenschaftlichen Heliozentrischen Glauben (in dieser Hinsicht sind Keplers Ausführungen in dem Optik-buch «Paralipomena ad vitellionem» besonders lehrreich).» [3]

Clarifying remarks

- [1] According to Kant, space and time are aprioristic forms of perception.
- [2] The concept of *archetype* is briefly explained in Letter 3. In 1952 Pauli published, together with the Swiss psychologist C.G. Jung, a volume 'Naturerklärung und Psyche' where Pauli put forward his treatise on Kepler 'Der Einfluß archetypischer Vorstellungen auf die Bildung naturwissenschaftlicher Theorien bei Kepler' and Jung introduced his concept of *synchronicity*, 'Synchronizität als ein Prinzip akausaler Zusammenhänge'.
- [3] Kepler's symbol of Trinity was a sphere where the centre represented the Father, the surface the Son, and the space in between was the region of the Holy Ghost. This he related to the Neoplatonian philosophy where the basis of existence is the "One" which creates the world by radiating its superabundance. Therefore, the Sun must be in the centre of the world, not the Earth.

Letter 3, 7 January 1948 (PC 0092.045)

Relationship between physics and psychology. Archetypes as expressions of a 'neutral' cosmic order, basic for both psychical and physical (material) world.

«*Zur Philosophie und Psychologie*. Die nun in Ihrem Vortrag formulierten Ideen haben viele Berührungspunkte mit meinen, z. B. Komplementarität u. Universalität samt Physik u. Psychologie, vielleicht sind aber auch Unterschiede. Mein Ausgangspunkt ist, welches die Brücke sei zwischen den Sinneswahrnehmungen und den Begriffen. Zugestandenermaßen kann die Logik eine solche Brücke nicht geben oder konstruieren. Wenn man die vorbewußte Stufe der Begriffe analysiert, findet man immer Vorstellungen, die aus «symbolischen»* Bildern mit im allgemeinen starkem emotionalen Gehalt bestehen. Diese Vorstufe des Denkens ist ein *malendes Schauen* dieser inneren Bilder, deren Ursprung nicht allgemein und nicht in erster Linie auf die Sinneswahrnehmungen (des betreffenden Individuums) zurückgeführt werden kann, sondern die durch einen «Instinkt des Vorstellens» produziert und bei verschiedenen Individuen unabhängig, d. h. kollektiv reproduziert werden. [1] (Dazu paßt, was Sie S. 12 und 13 über den Zahlbegriff gesagt haben.) Der frühere archaisch-magische Standpunkt ist nur ein klein wenig unter der Oberfläche; ein geringes abaissement du niveau mental genügt, um ihn völlig «nach oben» kommen zu lassen. Die archaische Einstellung ist aber auch die notwendige Voraussetzung *und die Quelle* der wissenschaftlichen Einstellung. Zu einer vollständigen Erkenntnis gehört auch diejenige der Bilder, aus denen die rationalen Begriffe gewachsen sind.

«Nun kommt eine Auffassung, wo ich vielleicht mehr ein Platonist** bin als die Psychologen der Jung'schen Richtung: [2] Was ist nun die Antwort auf die Frage nach der Brücke zwischen den Sinneswahrnehmungen mit den Begriffen, die sich nun reduziert auf die Frage nach der Brücke zwischen der äusseren Wahrnehmungen und jenen inneren bildhaften Vorstellungen? Es scheint mir – wie immer man es auch denkt, ob man vom «Teilhaben der Dinge an den Ideen» oder von «an sich realen Dingen» spricht – es muß hier eine unserer Willkür entzogene kosmische Ordnung der Natur postuliert werden, der *sowohl* die äußeren materiellen

* Vgl. C.G. Jung's Definition von «Symbol» in seinem Buch «Psychologische Typen». Das S. drückt einen «geahnten aber noch unbekannten Sachverhalt» aus. (Siehe die Defin. am Ende des Buches.)

** Es ist kein Zufall, daß Sie auf S. 13 Plato zitieren.

Objekte *als auch* die inneren Bilder unterworfen sind. (Was von beiden historisch das frühere ist, dürfte sich als eine müßige Scheinfrage erweisen – so eher wie <Was war früher: der Hahn oder das Ei?>) *Das Ordnende und Regulierende muß jenseits der Unterscheidung von <physisch> und <psychisch> gestellt werden* – so wie Plato's <Ideen> etwas von Begriffen und auch etwas von <Naturkräften> haben (sie erzeugen von sich aus Wirkungen). Ich bin sehr dafür, dieses <Ordnende und Regulierende> <Archetypen> zu nennen; es wäre aber dann unzulässig, diese als *psychische* Inhalte zu *definieren*. Vielmehr sind die erwähnten inneren Bilder (<Dominanten im kollektiven Unbewußten> nach Jung) die psychische Manifestation der Archetypen, die aber *auch alles* naturgesetzliche im Verhalten der Körperwelt hervorbringen, erzeugen, bedingen müßten. Die Naturgesetze der Körperwelt wären dann die *physikalische Manifestation der Archetypen*. Zu dieser Auffassung paßt sowohl Ihr Vorschlag, die Physik und Psychologie als komplementäre Betrachtungsweisen (bzw. Untersuchungsrichtungen) aufzufassen, als auch die eigentümliche Psychologie der Alchemie (die als archaische Stufe vor der eigentlichen Wissenschaft sehr aufschlußreich ist) so wie noch einiges Andere. Es sollte dann *jedes* Naturgesetz eine Entsprechung immer haben u. umgekehrt, wenn man auch heute das nicht immer unmittelbar sehen kann.»

Clarifying remarks

- [1] The collective 'instinct of presentation' can be understood, in terms of molecular biology, as the information stored in the DNA molecules characteristic of the human species. This information is approximately the same for all individuals and furnishes them with very similar instincts and reaction abilities.
During historical time, this genetic information has remained practically unchanged. Therefore the basic archetypes are the same now as they were in ancient times. Central conceptions belonging to religion, morality, and philosophy have, therefore, a timeless value and attractiveness.
- [2] According to Plato, the visible world is not a real world but only an incomplete image of the reality itself which is 'beyond' the perceived world. The real world is the *invariant world of ideas*. A model for this idea was obtained from geometry where some invariant relations and structures can be comprehended with absolute certainty.
Man has, according to Plato, an immortal soul which belongs to the world of ideas; in death it is separated from the material limitations and

it returns to the divine world of ideas. True knowledge is obtained with the aid of rational thinking, as if becoming reminiscences from the world to which our soul belongs.

Letter 4, 8 August 1948. (PC0092.052)

Conceptions of God and reality. Reality of symbols.

«Dieses bedeutet an sich noch nicht Gottesleugnung. [1] Mir erscheint das Unbefriedigende an letzterer, daß sofort eine neue Gottesidee (die dann besser als solche anzuerkennen ist) sich an die Stelle der geleugneten alten Gottesidee einfindet. (Schopenhauer hat den «Willen», Nietzsche den «Willen zur Macht» = das «herrische Weltspiel», Freud das «Über-Ich», moderne «Mystiker» wie A. Huxley haben den «divine ground».) *Etwas von der Gottesidee wird also immer bleiben.* Das Charakteristische an der Gottesidee der Modernen scheint mir, daß diesem Gott kein Bewußtsein zugesprochen wird (so wie auch Schopenhauers «Wille» bewußtlos ist). «Dieses Problem hängt sehr eng zusammen mit dem anderen Problem der *Idee der Wirklichkeit*. Der Laie meint gewöhnlich, wenn er «Wirklichkeit» sagt, spreche er von etwas Selbstverständlich-Bekanntem; während es mir gerade die wichtige und überaus schwierige Aufgabe unserer Zeit zu sein scheint, daran zu arbeiten, eine neue Idee der Wirklichkeit auszubauen. [2] Dies ist es auch, was ich meine, wenn ich immer betone, daß Wissenschaft und Religion etwas mit einander zu tun haben *müssen*. (Ich meine *nicht* «Religion innerhalb der Physik» und auch nicht «Physik innerhalb der Religion» – denn beides wäre ja «einseitig» – sondern Einordnung beider in ein Ganzes.) Was mir unter der neuen Wirklichkeitsidee vorschwebt, möchte ich versuchsweise nennen: die *Idee der Wirklichkeit des Symbols*. Ein Symbol ist einerseits ein Produkt der Anstrengung des Menschen, andererseits ein Zeichen für eine objektive Ordnung in Kosmos, von der der Mensch nur ein Teil ist. Es hat etwas vom alten Gottesbegriff und auch etwas vom alten Dingbegriff. (Beispiel innerhalb der Physik: «das Atom». Die primären Qualitäten der Raumerfüllung sind ja verloren gegangen. Wäre es kein Symbol, wie könnte es «sowohl Welle als auch Teilchen» sein?) Das Symbol ist symmetrisch in Bezug auf «Diesseits» und «Jenseits», d.h. zweiseitig in Sinne der von Ihnen vorgeschlagenen Auffassung des Erkenntnis-prozesses; es hat eine Beziehung zum «Beobachten» und zum «Begreifen», es kann mathematisch sein oder auch noch primitiver bildhaft. Das Symbol ist wie ein

Gott, der auf den Menschen wirkt, der aber vom Menschen verlangt, daß er auf ihn (das Gottes-Symbol) zurückwirken soll. Es scheint mir, daß nur so auch das Diesseits einen Sinn erhält und gerade das ist es, was mir bei Schopenhauer zu fehlen scheint. Bei ihm: «Pessimismus» als Gegensatzposition zu den «positiven Superlativen».»

Clarifying remarks

- [1] The first sentence in this quotation refers to Pauli's rejection of the «positive superlatives» (omnipotent, omniscient, etc.) generally associated with the conception of God.
- [2] This passage contains an interesting expression of Pauli's philosophical attitude; Pauli was not a positivist but rather a *realist*. He found, however, that modern physics forces us to change our conception of reality, being in contradiction with all traditional ontologies. Pauli characterizes his conception of reality, 'on trial', as *reality of symbol(s)*. His aim was to describe reality in terms which are 'neutral' with respect to the psychical 'inner world' and the physical 'outer world'. Symbols can have strong psychical importance but they also refer, simultaneously, to the outer world. Religion and metaphysics can be understood as containing descriptions of such a reality of symbols.
The philosophical attitude of Pauli shows that the Copenhagen interpretation of quantum mechanics is not bound to positivism. However, the 'naïve realism'—which is the normal attitude among natural scientists without philosophical interests—is not compatible with this interpretation. Those physicists who are not willing to accept a more abstract conception of reality are forced to avoid speaking of reality at all, and this makes them inclined toward positivism.

Letter 5, 3 November 1948 (PC0092.054)

The difference between Bohr's and Pauli's conceptions of reality.

«Ich möchte aber nochmals zurückkommen auf die Beziehung des in meinem Aufsatz («Hintergrundphysik») betretenen Standpunktes zum Artikel von Bohr im Planck-heft der «Naturwissensch.» (Nr. III von «Atomtheorie und Naturbeschreibung»). Die Frage dieser Relation wurde ja *von Ihnen* aufgeworfen. Inzwischen habe ich die in meinem letzten Brief zitierten Stellen dieses Bohr'schen Aufsatzes, die von Parallelen Physik–Psychologie handeln, nochmals mit C.A.Meier

durchbesprochen. Das Wesentliche ist, daß Bohr's Ausführungen ganz vom Standpunkt einer reinen Bewußtseinspsychologie aus geschrieben sind. Deshalb versteht Bohr auch unter «Einheit der Persönlichkeit» und unter «Einheit des Bewußtseins» etwas ganz anderes als wir. Es scheint mir deshalb, daß Bohr's Analogieen soweit sie Psychologisches betreffen (siehe das Schema in meinem letzten Brief, das diesen Analogieen entspricht) eine willkürliche Konstruktion ohne tiefere Bedeutung sind. Bohr verwendet den Begriff des Unbewußten *nie*; dieser Begriff liegt ihm so fern, daß er seine Bedeutung niemals erfaßt hat. Ich erinnere mich auch an diesbezügliche Gespräche. Er gab ohne weiteres zu, daß Träume als Informationsquellen benützt werden können – das hätten ja schon alle alten Völker getan – aber er bestand darauf, daß auch Träume Bewußtseinsinhalte seien. (In diesem Punkt war seine Haltung ähnlich derjenigen die ich bei Chinesen gefunden habe.) Zusammenfassend betrachte ich also den Standpunkt meines Aufsatzes als wesentliche Modifikation und Ergänzung von Bohrs Analogieen betreffend Physik–Psychologie, die sich ergibt durch Akzeptieren des Begriffs des «Unbewußten», wie er von modernen Psychologien Jung'scher u. anderer Richtung verwendet wird.»

Clarifying remarks

This letter describes a characteristic difference in the philosophical attitudes of Bohr and Pauli.

Bohr was not willing to accept, in his conception of reality, any element which, in principle, could not be described by using the methods of natural science. Jung's idea of synchronicity, which is essentially related to the psychology of the unconscious, must have been very strange to him.

Pauli's conception of reality, on the contrary, explicitly contained the unconscious in psychology, and in physics this brought in an irrational element (see letters 6 and 7). Pauli considered this consequence of quantum mechanics as very important, and its discussion is one of the basic themes in the correspondence between Pauli and Fierz. Recently d'Espagnat has arrived at a conception of 'veiled reality' (*réel voilé*), which is very similar to Pauli's 'reality of symbols'; in both cases reality can only be described incompletely with the aid of rational concepts. (B. d'Espagnat, 'A la recherche du réel', Gauthier-Villars, Paris, 1979.) Also David Bohm, although he wishes to maintain determinism, presents in his book 'Wholeness and the Implicate Order' (Routledge and Kegan Paul, London, 1980),

remarks which are not far from Pauli's thinking. All these physicists emphasize, for example, the comprehension of the *wholeness* of reality and the relationship between matter and consciousness.

Because of the limitations characteristic of his conception of reality, Bohr avoided speaking of the reality of microphysics. Therefore he was considered to be a positivist. I would like to describe Bohr, however, as a 'realist who was not able to form a conception of reality corresponding to his thinking'.

Letter 6, 26 November 1949 (PC0092.063)*

Statistical correspondence as a generalized causality, and its relationship with synchronicity. The non-causal behaviour of individual events.

«Ich bin vollkommen einig mit Ihnen in dem Unterschied zwischen Wiederholbarkeit (passiv) und <sich Wiederholen (aktiv)>, wobei ersteres für die physikalische, letzteres für die psychische <Situation> kennzeichnend ist. (In dieser Verbindung möchte ich daran erinnern, daß *Kramers* in seinem Handbuch-Artikel den Terminus <physikalische *Situation*> statt <Zustand> in der Quantenmechanik vorgeschlagen hat.) Um dieser Reproduzierbarkeit (die in der Problemstellung enthalten ist) willen, *degeneriert* das allgemeine <synchronistische> Phänomen in der Physik zur *statistischen* Vorhersagbarkeit des Verhaltens gleichartiger und gleichartig vorbehandelter Systeme. (Die Voraussetzung der Gleichartigkeit der betreffenden Systeme ist ja *nicht* im Begriff des synchronistischen Ereignisses von Jung enthalten!) Diese Auffassung der (nicht auf deterministische Kausalität zurückführbaren) Anwendung des mathematischen Wahrscheinlichkeitsbegriffes auf Naturvorgänge als *Degeneration* eines allgemeinen Falles, möchte ich hiermit zur Diskussion stellen. (Es kommt mir eben so vor, wie wenn hier nur *ein* Gegensatzpaar – statt zwei – mitspielen würde, wie bei einem platt gedrückten Mandala, wobei ich das <in die Länge ziehen> als Bild der Reproduzierbarkeit anwende). [1]

«Um sodann das *positive* Prinzip, das den Gesetzen der Quantenmechanik zu Grunde liegt, zu benennen, kam mir Bohrs Ausdruck <Korrespondenz> zu Hilfe. (Nach Aufstellung der Wellenmechanik spricht er immer noch von einem <Korrespondenzargument> – siehe <Naturw.> 21, 245–250, 1933 speziell den Passus S. 246, 2. Spalte oben.) Jenes statisti-

* The dating '26 September 1949' mentioned in the Pauli Collection must be incorrect.

sche Verhalten der vielen gleichen Einzelsysteme, die keinerlei Kontakt mit einander haben (〈fensterlose Monaden〉), ohne doch andererseits kausal determiniert zu sein, ist ja in der Quantenmechanik als *letzte*, nicht weiter reduzierbare gesetzmäßige Tatsache aufgefaßt (etwa wie bei Galilei die gleichförmig beschleunigte Fallbewegung). In meinem in der Zeitschr. 〈Experimentia〉 im Abdruck befindlichen Vortrag über Komplementarität habe ich daher versucht, den Ausdruck 〈Korrespondenz〉 etwas allgemeiner als Bohr eben die positive Seite der quantenmech. Naturbeschreibung kennzeichnend verwenden. Es ist ja diese *statistische Korrespondenz* welche zwischen Kontinuum (Wellenbild) und Diskontinuum (Teilchenbild) vermittelt. (Dies etwas allgemeiner als Vermittlung zwischen 〈Quantentheorie〉 u. 〈klassischer Theorie〉 bei Bohr). [2] Dort habe ich nicht ausdrücklich erwähnt, daß mir beim Terminus 〈Korrespondenz〉 die geistige Abstammung von der 〈correspondentia〉 des Mittelalters (〈Entsprechungen〉) deutlich hindurchzuschimmern scheint. In beiden Fällen handelt es sich doch um eine die gewöhnliche Kausalität transcendierende Form der gesetzlichen Naturbeschreibung, die auf irgend eine Art von Analogien basiert ist. (Dies ist auch der Fall bei Leibnizens prästablierter Harmonie.)

«Die Einzelsysteme der Quantenmechanik sind 〈fensterlose Monaden〉 und doch findet sich stets der richtige Bruchteil, der wie berechnet reagiert (abgesehen natürlich von den vorgesehenen statistischen Schwankungen). [3]

«Das tertium comparationis des quantenmechanischen Falles mit dem des synchron. Phänomens ist *das aufeinander abgestimmte Verhalten verschiedener* (deterministisch-kausal nicht verbundener) *Ereignisse*. (Hierauf beruht ja der Begriff 〈physikalische Situation〉 in der Quantenmechanik, *nicht* auf einer direkten gegenseitigen Beeinflussung der betreffenden Objekte.)

«Die quantenmechanische Situation ist natürlich nicht *nur* eine Degeneration der allgemeinen 〈Synchronizität〉 (dies als hier vorgeschlagene Arbeitshypothese verstanden) sondern *auch* eine 〈rationale Verallgemeinerung〉 der gewöhnlichen deterministischen Kausalität (Bohr). Wenn der Bruchteil 1 ist (statt zwischen 0 und 1), es ist das ja ein besonderer Grenzfall, als der ja die alte determ. Kausalität, von der Quantenmechanik aus betrachtet, erscheint. Ich habe keinen Zweifel, daß die quantenmechanische 〈statistische Korrespondenz〉 viel näher auf der Seite des alten Determinismus liegt als auf der Seite des Synchronizitätsphäno-

mens. Vom letzteren aus betrachtet muß die Quantenmechanik als eine *sehr schwache* Verallgemeinerung der alten Kausalität erscheinen. Und doch scheint mir die Quantenmechanik auch jenen Wegweiser nach der anderen Richtung zu haben, wo von willkürlicher Reproduzierbarkeit keine Rede mehr sein kann. Die Quantenmechanik scheint mir eine Art *Mittelstellung* einzunehmen. [4]

«Dies ist meine momentane Ansicht, zu der die Überlegungen Ihres Briefes gar nicht schlecht zu passen scheinen. Der *Erfolg* des *reasonable belief* – und damit auch die Möglichkeit von Naturgesetzen – scheint mir *stets* auf einer archetypisch bestimmten Koinzidenz unserer Erwartung (psychisch) mit einem äußeren Naturvorgang (physisch) zu beruhen. Für den unanschaulichen Anordner gibt es eben die Unterscheidung *physisch-psychisch nicht*. Es kommt mir aber mehr und mehr so vor, als ob das *naturwissenschaftliche Denken* in dieser Hinsicht nur ein Spezialfall von allgemeineren Möglichkeiten wäre. Vielleicht kommen wir darauf noch zurück. (Es hängt mit der *Vorbehandlung* zusammen.)»

Clarifying remarks

- [1] The mentioning of one or two ‘pairs of opposites’ and of ‘mandala’ have a connection with the ‘problem of the fourth’ or of ‘quaternity’ which is much discussed in this correspondence. This problem is omitted here because it would require rather much space.
- [2] The generalized concept of causality, which Pauli calls here *statistical correspondence*, has also been called *statistical causality*. For example, Academician V. Fock, in his discussions with Bohr about the philosophical foundations of quantum mechanics, in 1957, emphasized this concept and called it statistical causality. (This visit to Copenhagen was important for the rehabilitation of the Copenhagen interpretation in the Soviet Union.) Bohr has not explicitly used this concept but has, instead, presented complementarity as the generalized conception of causality characteristic of quantum mechanics. Statistical correspondence/causality is, however, more definitely a generalized concept of causality which contains the classical causality (absolute or deterministic causality) as a special case.
- [3] The ‘irrational’ comes into quantum theory in the form of the non-causal behaviour of individual systems; cf. Letter 7.
- [4] Because *synchronicity* is explicitly related to *non-causal* connections, the statistical causality/correspondence contains both a ‘causal’ and a

‘synchronical’ element. Pauli expresses here the eventual need of a still more general conception of ‘causality’ than that of ‘statistical correspondence’, in order to come to the level of Jung’s synchronicity.

In this article we must limit the discussion of synchronicity to these very loose remarks.

Letter 7, 13 October 1951 (PC0092.078)

The influence of the Italian Renaissance and Neoplatonism on Newton’s conception of space. The ‘anima mundi’ (world soul) and its ‘revenue’ in modern physics.

«Lieber Herr Fierz,

«Ihr Brief vom 10. hat mich außerordentlich interessiert und ich will versuchen, teils widersprechend, teils ergänzend einiges hierzu zu bemerken.

.....
«2. Ich komme nun von der Physik des 20. Jahrh. sogleich zurück auf Newton und sogar noch etwas weiter zurück: zur Naturphilosophie der italienischen Renaissance. Das hat sehr viel mit dem Ende Ihres Briefes zu tun, der von Newton handelt; es ist ganz sachgemäß, denn das Ende enthält latent den Anfang und das noch Ältere ist immer das Neue (mit welcher Formel ich immer gerne die Konservativen und die Umstürzler zugleich widerlege). Die Funktion der englischen Neuplatoniker bei Newton war offenbar, die Verbindung mit der Naturphilosophie der Renaissance herzustellen, denn damals war man sehr neuplatonisch (seit Ficino oder wahrscheinlich schon länger) und DAMALS *hat sich auch der Raum gegenüber den Dingen verselbständigt (= materialisiert)*! Nach meiner Ansicht handelt es sich dabei um die Vorwegnahme einer Wendung der Naturwissenschaft durch die Philosophie: Man mußte wegkommen von der peripatetischen Tradition, wonach die Dinge «einen Ort suchen», was mit der Vorstellung begründet war, *daß die Orte im Raum solche physikalische Qualitäten haben*. Diese These war in der Renaissance *kontrovers* geworden, von vielen beibehalten (sogar von dem sehr neuplatonischen Giordano Bruno – bei diesem die *Unendlichkeit* des Raumes ermöglicht ihm Pantheismus) aber von anderen verworfen. Von letzteren möchte ich auf Grund meines sehr lückenhaften historischen Wissens (möge es von Basel aus – gesegnet sei diese humanistische Polis – ergänzt werden!) Bernardino *Telesio* (1508–1588) und Francesco *Patrizzi* (1529–1597) erwähnen. Ersterer leugnete die physikalischen Qualitäten der Raumpunkte (wenn ich nicht irre, bedeute es auch deren vollkom-

mene Gleichwertigkeit, d.h. – modern ausgedrückt – die Homogenität des Raumes), letzterer verfocht die «absolute» Existenz des Raumes *jenseits der Dinge*. (Man sehe auch noch bei *Campanella* nach!) – Man kann nicht genug betonen, wie *sehr* die Probleme von Leibniz, Spinoza und Newton in der italienischen Renaissance aufgerollt waren!

«Zum Neuplatonismus der Renaissance (siehe Ficino) gehört aber auch wesentlich die *anima mundi*, die auch «anima movens» war. [1] Jeder Planet hatte eine Einzelseele, doch wie kamen diese miteinander in Beziehung: auch noch seelisch, durch die *anima mundi*, an der ja die Einzelseelen *Teil* haben. (NB. Ich sehe Herrn Fludd vor mir, wie er bei einem Wort «Teil» sofort die Stirne runzelt – also sagen wir ihm zu liebe: «mit der die Einzelseelen, sofern sie dem lichten Prinzip angehören, identisch sind»). «Im 17. Jahrh. jedoch kam die *anima mundi* aus der Mode, diese Idee *verblaßte* (gerne würde ich wissen wie Ihr Epigone H. More u. sein Kreis sich dazu gestellt hat – was ist das noch für ein Neuplatonismus *ohne* die *anima mundi*?) und eben durch die so entstandene Lücke drang Proportion, Geometrie, Mathematik in die Ideen über die Bewegung ein und drängte zur Empirie, zur Messung. Man sieht diesen Prozeß deutlich nicht nur bei Kepler, sondern auch bei Galilei. Dieser *verwarf* nicht nur die aristotelisch-peripatetische Tradition sondern auch den *Neuplatonismus* einschl. *anima mundi* und ging auf die Pythagoräer *und auf Pluto selbst* zurück («das noch Ältere ist immer das Neue»!)

«Mit diesem Fortschritt (analytische Geometrie – Newton'sche Mechanik) aber entrückte der Raum in den Olymp des Absoluten und die Beziehung von Seele u. Materie wurde ein besonderes Problem, das im Dämmerlicht des «Parallelismus» verschwand so wie die Venus in der Morgendämmerung verschwindet.

«Nun scheinen wir aber zu beginnen, darausher zu leiden, daß man im 17. Jahrhundert zu weit gegangen ist (vgl. meine Keplerarbeit) und von damals her kommen «revenues»* die mich nachts, und zuweilen auch tags, verfolgen – so wie die Venus als Abendstern zurückkehrt**.

* Skandinavisch: «Gengangere» (zugleich Titel des bekannten Stückes von Ibsen). Die Silbe *gen* ist durch Wortstamm wie das englische *again* (= wieder). D.h. natürlich, daß das englische Wort aus dem älteren dänischen (*igen*) abgeleitet ist.

** Ich glaube, daß *jede* Vermehrung des Bewußtseins *so* vor sich geht, daß dabei auch etwas im Unbewußtsein verschwindet, was vorher bewußt war und was immer viel später wiederkehrt. Das will ich mit dem Bilde des Venus ausdrücken und auch mit dem Spruch «das noch Ältere ist immer das Neue».

«Wenn etwas Unsichtbar wird, so bleibt es doch wirksam vorhanden und schon hat die allgemeine Rel.-theorie in ihrem durch die Dinge <gekräuselten> <Zeit-Raum> die von den Peripatetikern überlieferte Idee der physikalischen Qualität der Raumpunkte (<Orte>) in der verwandelten Gestalt des g_{ik} -Feldes zurückgebracht (wenn sie auch nicht gleich den ganzen horror vacui zurückbringen konnte!) [2]

«3. Nun kommt die große Krise des Wirkungsquantums: man muß das Einmalige und den <Sinn> desselben opfern, um eine objektive u. rationale Beschreibung der Phänomene zu retten. Wenn zwei Beobachter dasselbe tun, ist es wirklich auch physikalisch nicht mehr dasselbe: nur die *statistischen Durchschnitte* bleiben im allgemeinen dieselben. *Das physikalisch Einmalige ist vom Beobachter nicht mehr abtrennbar* – und geht der Physik deshalb durch die Maschen ihres Netzes. Der Einzelfall ist *occasio* und nicht *causa*. Ich bin geneigt, in dieser <occasio> – die den Beobachter und die von ihm getroffene Wahl der Versuchsanordnung mit einschließt – ein <revenue> der in der 17. Jahrhundert abgedrängten *anima mundi* (natürlich in verwandelter Gestalt) zu erblicken. *La donna è mobile* – auch die *anima mundi* und die *occasio*.

«Es ist hier etwas offen geblieben, was früher geschlossen schien und meine Hoffnung ist, daß durch diese Lücke *neue Begriffe* an Stelle des <Parallelismus> eindringen werden, die einheitlich *zugleich* physikalisch und psychologisch sein sollen. [3] Möge eine <glücklichere Nachkommenschaft> dies erreichen.»

Clarifying remarks

- [1] In the subsequent letters (not quoted here), the introduction of the ‘*anima mundi*’ and the development leading to the present conception of matter, as a substance independent of consciousness, has been described in detail. The author recommends that at least this part of the correspondence between Fierz and Pauli should be published independently of the general edition of Pauli’s letters, furnished with appropriate clarifications.
- [2] The introduction of the metric field g_{ik} in the General Theory of Relativity, as some kind of ‘*revenue*’ of the ‘*anima mundi*’, has been discussed in the first part of this letter. It was left out here because it would also require quotations from subsequent letters, where the role of space in modern physics is discussed further.
- [3] *Parallelism* (mentioned twice in this letter) means the opinion, intro-

duced by cartesians, that *mind* and *matter* are mutually independent but ‘parallel’ elements of reality, the connection between them being, originally, accomplished by God. *Matter* is characterized by *extension*, *mind* by *thinking*. It is then supposed that psychical phenomena, too, can be considered as material phenomena in the brain whence one gets a ‘parallel’ description of the actual spiritual phenomena.

4.2 *Translation of these excerpts into English*

As explained in Section 4.1, the most essential parts of each quotation are given here in English.

Letter 1, 30 March 1947 (PC 0092.039)

“I am increasingly expecting a further upheaval in fundamental physical concepts, considering, in particular, that the manner in which the space-time continuum is introduced is for me ever more unsatisfactory. (It is, of course, a masterly idea to use time no longer to allocate causal series, as once upon a time, but as an arena for probabilities. If, however, we replace ‘masterly’ by ‘foolhardy’, we should be at least just as correct. In fact, something happens only during observation when, as Bohr and Stern have finally convinced me, entropy must increase. *Nothing at all* occurs *between* observations; *only time* has ‘meanwhile’ irreversibly progressed on the mathematical papers!)

“This space-time continuum has now become a shirt of Nessus which we can no longer take off. (Instead of ‘shirt of Nessus’ you could also use the word ‘prejudice’ [in German ‘Vorurteil’], but that would firstly be too innocuous and secondly would shift the error too far from the pure assumption to the judgement [in German ‘Urteil’].)”

Letter 2, 29 December 1947 (PC 0092.044)

“I have in the meantime continued my excursion into the 17th century. That Newton virtually placed space and time at the right hand of God, in the place left vacant by his driving out of God’s son, is a cutting episode from the history of ideas of which I first became aware from reading your paper on Newton. It is well known that a tremendous spiritual effort was

then needed to bring time and space back from this Olympus. This work was artificially made even more difficult by Kant's philosophical attempt to bar access to this Olympus from the human mind.

"I therefore find particularly interesting the period when space and time were *not yet* up there, and especially the moment immediately preceding this fateful operation. Hence my study of Kepler. ... Kepler uses the word 'archetype' and also 'archetypical' in a sufficiently similar way to that in which Jung uses these concepts and there is therefore no need to stress any special difference. ... I thus believe that I can show, from Kepler's writings, a possibly not uninteresting connection between his spherical symbol of Trinity and his passionate, heliocentric belief. ..."

Letter 3, January 1948 (PC0092.045)

"... My starting point is the question of the bridge between sensory perceptions and the concepts. Admittedly, logic can neither provide nor build such a bridge. If the aforementioned stage of the concepts is analysed, ideas are invariably found which consist of 'symbolic' images with a generally strong emotional content. This preliminary stage in thinking is a *representation* of these inward images, the *origin* of which cannot generally and primarily be traced back to the sensory perceptions (of the individual concerned), but which are produced by an 'instinct for presentation' and are reproduced independently by various individuals, that is to say, collectively. ... The archaic attitude is, however, also the necessary prerequisite *and the source* of the scientific attitude. A full understanding also requires that of those images from which the rational concepts have grown.

"Now there comes a conception in which I am perhaps more of a Platonist than the Jungian psychologists: What is the answer to the question concerning the bridge between sensory perceptions and the concepts, which is now reduced to the question concerning the bridge between the outward perceptions and those inward figurative conceptions? It seems to me—however it is thought, whether we speak of 'the participation of things in ideas' or of 'inherently real things'—that we must postulate a cosmic order of nature beyond our control to which *both* the outward material objects *and* the inward images are subject. ... *The ordering and regulating must be placed beyond the difference between 'physical' and 'psychical'*—as Plato's 'Ideas' have something of the concepts and also something of the 'natural forces'. ..."

Letter 4, 12 August 1948 (PC0092.052)

“... I feel that the unsatisfactory factor in the latter [the denial of God, author’s remark] is that a new idea of God ... is immediately put in the place of the old, denied one. (Schopenhauer has the ‘will’, Nietzsche the ‘desire for power’, Freud the ‘super-ego’, etc.) *There will thus always remain something of the idea of God.* ...

“This problem is very closely related to the other problem of the *idea of 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. This is also what I mean when I continuously stress that science and religion *must* be connected in some way. (I do *not* mean ‘religion within physics’, nor ‘physics within religion’, since both would be ‘unilateral’, but rather the arrangement of both within a whole.) I could call what I feel by the new idea of reality, by way of trial, *the idea of the reality of the symbol*. ... The symbol is symmetrical in relation to ‘this side’ and ‘beyond’, i.e. ... it has a relationship to ‘observation’ and ‘conception’; it may be mathematical or also more primitively figurative. ...”

Letter 5, 3 November 1948 (PC0092.054)

“... The essential is *that Bohr’s exposition is written entirely from the point of view of a pure psychology of consciousness*. By ‘unity of personality’ and ‘unity of consciousness’, therefore, Bohr understands something quite different from us. I therefore feel that Bohr’s analogies, where they concern the psychological, ... are arbitrary constructions, without any deeper significance. Bohr *never* uses the concept of the unconscious; it is so far from his thinking that he has never grasped its meaning. I also remember talks on this subject. ... To summarize, I thus regard the basis of my essay as an essential modification and supplement to Bohr’s analogies concerning physics-psychology, arising from the acceptance of the concept of the ‘unconscious’, as used by modern psychologists of the Jungian and other schools.”

Letter 6, 26 November 1949 (PC0092.063)

.....
“Bohr’s ‘correspondence’ then helped me in naming the *positive* principle underlying the laws of quantum mechanics. ... That statistical behav-

ious of the many like individual systems without any mutual contact ('windowless monads'), yet without being otherwise causally determined, is regarded in quantum mechanics as the *final*, irreducible fact of lawfulness. ... In my article on complementarity to be printed in the periodical 'Experimentia' I have thus tried to use the expression 'correspondence' in a rather more general manner than Bohr, as characterizing the positive side of the quantum-mechanical description of nature. It is indeed this *statistical correspondence* that reconciles the continuum (wave image) and the discontinuum (particle image). ...

"The individual systems of quantum mechanics are 'windowless monads' and there is, nevertheless, always the right fraction which reacts according to calculations (apart, of course, from the predicted statistical fluctuations).

"The tertium comparationis in the quantum-mechanical case with that of the synchronous phenomenon is the *mutually attuned behaviour of different* (not deterministic-causally connected) *occurrences*. ...

"The quantum-mechanical situation is, of course, not *only* a degeneration of the general 'synchronicity', ... but *also* a '*rational generalization*' of the usual deterministic causality (Bohr). If the fraction is 1 (instead of between 0 and 1), we do have a special borderline case in which form the old deterministic causality appears, viewed from the quantum-mechanical standpoint. ... Quantum mechanics seems to me to take up a kind of *central position*. [Pauli means: central position between the conventional causality and Jung's synchronicity. Author's remark.]"

Letter 7, 13 October 1951 (PC0092.078)

"The neo-Platonism of the Renaissance (see Ficino) also essentially embraces the *anima mundi*, which was also 'anima movens'. Every planet has its own soul, but how did they come into a mutual relationship: still spiritually, through the *anima mundi* in which the individual souls have a *part*. ...

"In the 17th century, however, the *anima mundi* went out of fashion, and the idea *faded away* ... and through the opening thus left there penetrated proportion, geometry, and mathematics into the ideas of motion, resulting in a compulsion towards empiricism and measurement. This process can clearly be seen not only in Kepler but also in Galileo. He *rejected* both the Aristotelian-peripatetic tradition and neo-Platonism,

including the *anima mundi*, returning to the Pythagoreans and to *Plato himself*. ('What is still older is always new'.)

"With this progress (analytical geometry, Newtonian mechanics), however, space retreated into the Olympus of the absolute, and the relation of mind and matter became a special problem which disappeared in the twilight of 'parallelism' as Venus disappears in the dawn light.

"We now seem to have started to suffer from the fact that we went too far in the 17th century (cf. my work on Kepler), from which time come 'revenues' * which haunt me at night and also sometimes by day, just as Venus returns as the evening star **.

"When something becomes invisible, it still remains present in fact, and already the general theory of relativity in its 'space-time' 'rumpled' by things has brought the idea of the physical quality of space points ('places') back in the transformed image of the g_{ik} -field (even if it could not quite bring back the entire *horror vacui*).

"3. Now comes the great crisis of the quantum of action: the individual case and its 'logic' must be sacrificed in order to save an objective and rational description of phenomena. When two observes do the same thing, it is actually no longer the same, even in physics: only the *statistical mean values* remain generally the same. *The physical individual case can no longer be separated from the observer*, and it thus passes through the meshes of the net of physics. The individual case is *occasio* and not *causa*. I am inclined to see in this *occasio* ... a 'revenue' of the *anima mundi* suppressed in the 17th century ('in another form', of course). *La donna è mobile*—as are the *anima mundi* and the *occasio*.

"Something that previously appeared closed has remained open here, and I hope that *new concepts* will penetrate through this gap in the place of 'parallelism', and they should be uniformly *both* physical *and* psychological. May 'more fortunate offspring' achieve this."

* Scandinavian: "Gengangere" (also title of Ibsen's well-known play, in English "Ghosts"). ...

** I believe that *every* increase in consciousness occurs in such a way that something also disappears into the unconscious, something which was previously in the conscious and later returns again and again. This is what I want to express with the Venus image and also with the proverb 'What is still older is always new'.

5. The irrational element of reality

It is not possible within one hour to give more than some scattered traits of the rich material which the correspondence between Pauli and Fierz contains. In particular their opinions concerning the revolution which took place from the late Middle Ages, until the 17th century, would be well worth publishing¹⁰. Physicists can understand changes in such concepts as space, time, and matter, or in the concept of causality, in some respects better than philosophers or historians. Pauli and Fierz have very carefully studied the history of ideas, in this respect, from the very beginning of Western culture, and especially *the separation of space from matter which took place in the 17th century*, culminating in Newton's concepts of absolute space and absolute time.

This historical study gave, for Pauli, the background for a judgement of the present situation in physics. The criticism he directed towards the present use of the concepts of space and time was not based just on metaphysical prejudices: it was a conviction based on an exceptional knowledge of the development of ideas through the ages.

This was also the reason why Pauli, in his conception of reality, came to different viewpoints from most physicists and philosophers interested in the interpretation of quantum mechanics. Pauli's conception of reality contained an *irrational element* which for most scientists and philosophers would mean the same as betraying the very idea of science. Pauli's judgement of the present situation was, however, that people are accustomed, in science, in philosophy, and even in theology, *to suppress the irrational, the evil, the dark in reality*. Western thinking is based on the assumption that everything is, of its very nature, rational and good. *The irrational element of reality—or the dark side of God—is something impossible, according to Western thinking*. Only such things are acknowledged to exist—to belong to reality—which can be understood in a rational way. The irrational must, in some way, always be excluded.

In physics and in modern science in general, this suppression of the irrational reaches its expression in the idea of *determinism*. Nothing can happen without rational causes. Everything must be analysable in a rational way. These are prejudices characterizing the modern attitude.

According to Pauli, it is a very difficult task of our time to find a way out of these prejudices. We must try to *take off the shirt of Nessus* which the revolution of the 17th century has woven. It is time to acknowledge the irrational element of reality—and the dark side of God.

Mystics have, at all times and in all parts of the world, understood that the rational structure of the world is not the very essence of reality. *There is* something for which such human concepts as rational–irrational, good–evil, cannot be applied at all. If we, human beings, try to form a true conception of God, we *must* also acknowledge His irrational and destroying side. This cannot be avoided because we can only incompletely describe transcendental things with the aid of our rational concepts.

There is, however, another way of comprehending reality than rational analysis and experiencing. The mystical comprehension of reality makes one understand that God is neither rational, nor irrational, neither good, nor evil—or He is both of them at the same time. Reality has complementary features, it contains both light and dark. If we, in our rational analysis of the world, reject the existence of the evil and the irrational, we make a fundamental error which leads us astray to seek unrealistic aims, both in life and in science.

But does this have anything to do with physics? Is it not a little too strange that I am speaking of mysticism at CERN?

My excuse is that I had to describe Pauli's philosophy. I am just doing my best in trying to describe some essential features of it *. But let us think of the question of what this has to do with physics.

6. Where is physics going?

Pauli considered the Copenhagen interpretation of quantum mechanics to be the only right interpretation of this theory, and for him, this meant an essential progress in scientific thinking **. Einstein's criticism only showed, to Pauli, that Einstein was not able or willing to see anything else in the world than its rational order. The famous Einstein-Podolski-Rosen 'paradox' ¹¹ was no problem at all for Pauli. That locally isolated parts of a closed system seem to have instantaneous actions at a distance is not surprising if

* The suppression of the 'irrational' in modern Western thinking and questions related to mysticism are discussed, for example, in Pauli's letter to Fierz of 11 October 1953 (PC 0092.120).

** The term 'Copenhagen interpretation of quantum mechanics' is not unambiguous, because there are differences in the philosophical attitudes of Bohr, Heisenberg and Pauli, for example. There are, however, enough common features to justify this term in the sense of a 'first approximation'.

we think that the concepts of space and time are not applicable to microphysical systems in the same way as we are used to apply them in the macroworld. Quantum mechanics gives only a ‘blurred’ kinematical description, and it seems to correspond to reality in microphysics. It is, according to Pauli, a step in the right direction, even if it is not the final solution of the space-time problem in the microworld.

Attempts to rescue determinism in microphysics, for instance by using some ‘hidden parameters’, were criticized very sharply by Pauli¹². By trying to maintain a possible exact space-time description, these theories try to turn around the sound development started by quantum mechanics. Pauli expected progress from the exactly opposite direction, from a still more restricted use of space-time description in microphysics.

That quantum mechanics with its ‘blurred’ kinematics has made physicists abandon the idea of absolute causality (i.e. determinism), Pauli considered to be an essential step forward. The irrational element which Western culture has tried to suppress has come to physics in the form of the *non-predictability of the individual events*. Only *mean values* (expectation values) can be subjected to rational analysis. All individual events contain an irrational element—and this is a step in the right direction.

During the last few years of his life Pauli expressed concern about the general trend of physics research¹³. He wrote, for instance, to Fierz that his generation would go down in history as a generation which saw very deep problems but was not able to solve them. But he had the impression that the following generation did not see those problems at all. He said that physicists are becoming technicians who are only interested in special problems and not in *the whole*.

If I try to guess what Pauli meant with the very deep problems he saw, I would especially like to mention the following two:

- i) The role of space and time in the microworld.
- ii) The psycho-physical problem.

Pauli was not satisfied with present field theories. In spite of the great progress in this field, I guess that Pauli would say that the most essential problems are still untouched. In present theories space-time still has a role which is a relic of the absolute space of Newton. Einstein tried to eliminate absolute space and absolute time, but Pauli and Fierz present arguments which show that his success was only partial. Even in the general theory of relativity space-time has an ‘absolute’ role, e. g. in the sense that space-time

can exist also in the form of a vacuum, without any matter. This is even more clearly true of other field theories, also in their quantized form.

Space, time, and matter form an inseparable whole, but in the late Middle Ages and finally in Newton's physics they were separated, by supposing that space and time can have an independent existence, in principle*. This was enormous progress at that time, but we should remember that this is only a simplified description of reality. Especially the introduction of space-time *continuum* into quantum theory is not yet clear enough.

The second problem concerns the relationship between physics and psychology. It very much occupied Pauli's interest during his last ten years. His opinion was that this field belongs to physicists as much as to psychologists. I do not think that I am in error if I say that Pauli expected real progress also in physics itself to come from this field. He writes that the psycho-physical problem is for our time the same as the exploration of heavenly spaces was for the scientists in the 17th century¹⁴.

Without going into any details I would like to characterize this problem in the following way. Descartes, who stressed the requirement of clear and distinct concepts, divided reality up in a way which has been characteristic of thinking afterwards. His conception of reality can be represented by a triangle; one corner point represents 'God', a second one 'me' or 'I', and the third one the 'world'. 'I' can also be called 'consciousness' or 'mind', and the 'world' means the material outer world which is supposed to be without 'consciousness' and independent of it. Instead of 'world' one can speak of 'matter'. The connection between 'mind' and 'matter' is, according to Descartes, contained in the conception of 'God'.

In later times, the emphasis has been on the investigation of 'matter'. Simultaneously, people have more and more forgotten one part of reality: 'God'. Then 'mind' and 'matter' have remained without any innate connection. Critical thinkers begin now to feel the understanding of the relationship between 'mind' and 'matter' to be important and pressing. The main trend in physics, however, does not show any special interest in this field, and also psychology preferably avoids such questions. But there are signs that interest in the mind-matter problem is increasing.

* The ancient atomists already assumed the existence of *void* as independent of *atoms*. In the 17th century this idea was generally accepted, and after that the scientific view of the world has been based on this assumption.

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Address: CERN/SIS, CH-1211 Geneva 23, Switzerland.

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¹ WPL I, p. 13.

² A. Einstein, *Naturwissenschaften* 10 (1921) 184.

³ WPL I, p. 7.

⁴ WPL I, p. 58.

⁵ PC 0092.107; Pauli's letter to Fierz, no date.

⁶ W. Pauli, Mercurperihelbewegung und Strahlenablenkung in Weyls Gravitationstheorie, *Verh. d. Deutschen Phys. Gesellschaft* 21 (1919) 742.

⁷ WPL I, p. 21.

⁸ WPL I, p. 189.

⁹ W. Heisenberg, Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen, *Z. Phys.* 33 (1925) 879.

¹⁰ M. Fierz, Über den Ursprung und die Bedeutung der Lehre Isaac Newton's vom absoluten Raum, *Gesnerus (Sauerländer, Aarau)* 11 (1954) 62. This article is closely related to the correspondence Pauli–Fierz.

¹¹ A. Einstein, B. Podolsky and N. Rosen, Can quantum-mechanical description of physical reality be considered complete? *Phys. Rev., ser. 2*, 47 (1935) 777.

See also *Dialectica* 2, 3/4, articles by Bohr, Einstein and Pauli (editorial).

¹² Hidden variables proposed by *D. Bohm* are discussed in several letters between Pauli and Fierz in 1952 (the first letter is PC 0092.084; Pauli's letter to Fierz, 6 January 1952).

¹³ cf. e.g. PC 0092.140, 14 September 1954; PC 0092.164, 14 January 1956; PC 0092.2164, 13 May 1958, and PC 0092.2167, 9 July 1958.

¹⁴ PC 0092.144, Pauli's letter to Fierz, 26 October 1954.

Abstract

During the last 10 to 15 years of his life, Pauli spent much time studying the history and philosophy of science. His starting point was the philosophy of quantum mechanics, but this led him on to psychology, the history of ideas, and many other fields, not least the relation of religion to natural science.

The article is a somewhat enlarged version of a colloquium given at CERN (Geneva) and is based on Pauli's letters to Markus Fierz, then professor in Basle. From these letters one gets a picture of Pauli which essentially differs from that usually held.

Zusammenfassung

Der Physiker Wolfgang Pauli vertiefte sich in den letzten 10–15 Jahren seines Lebens intensiv in die Geschichte und Philosophie der Naturwissenschaften. Die Quantenmechanik führte ihn zur Psychologie, der Ideengeschichte, und zuletzt zur Frage der Beziehungen zwischen Religion und Naturwissenschaften. Der Autor verfolgt diese geistige Entwicklung anhand von Briefen, die Pauli an Prof. Markus Fierz, damals in Basel, schrieb.

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