Complementary education course for physics teachers 2011. *The empirical basis of modern physics.*
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5. THE ONTOLOGICAL CRISIS OF MODERN PHYSICS

Goodbye to the classical elements of reality

Transition to modern physics is not a revolution in the sense, that the old structures would be destroyed. The classical mental imagery is an intermediate stage of the structural perception, a set of "finished gestalts", justified by empirical compulsion on their own area of validity. Our primary mental imagery concerning the nature of reality ranges, however, much wider than our senses. Observational instruments and experimental devices, as extensions of our sensory abilities, support the structural perception, extrapolating the imagery gradually to the whole phenomenal world of classical physics. But at the entrance gate of modern physics an insuperable limit is encountered.

The *conceptual facility* necessary for the amendments means *possession of the classical mental imagery* in the "structure of mind" as basic material of the proceeding process, including the *sense of magnitudes* born in quantification. Mental images cannot be changed without knowing the mental images to be changed. A new, hierarchically higher layer of structural perception is required, where a new kind of mental imagery, based on the new empiry, is born about the nature of time, space, entities and phenomena. The revolutionary aspect here is, that the functioning of the old structures does not extend to the new areas reached by the new empiry, and that the requirements of modification of the mental images are so violent.

The *ontological crisis* arises from the fact, that the *new image of reality*, such as one ought to perceive it in front of the empirical compulsion, is *totally different from the reality of the macro world,* revealed to us in the primary perception.

The *attitudinal facility*, readiness to accept the *empirical compulsion*, is put to a severe test. The classical imagery concerning the nature of the "elements of reality", as discussed on the previous lecture, must now be seen as preconceptions to be amended, just as the preconceptions of the pupils, widely studied and discussed in literature, must be modified on their first steps towards conceptual understanding of physics.

The experimental research accumulated gradually material, which lead to severe contradictions with the classical basic imagery. Around 1920 the foundations of the mental images had already, due to empirical compulsion, strongly shaken, and the understanding based on them was in a crisis. This *crisis still continues in the physics studies of today.* I am calling it *ontological crisis* because it profoundly concerns everything described above as "elements of reality" i.e. our mental images about time, space, entities and phenomena.

Here, we encounter the *problem of language*, common to all of us. It becomes strongly pronounced in *teaching* and in the continuous vain attempts to *popularise* modern physics. Our language is tightly bound to the classical mental imagery rooted in the primary perception. For teaching and popularisation, there is no better language available, which would enable us to speak of the new mental images violating our ideas about the "elements of reality", firmly established in our minds. Therefore, *when trying to describe, in this language, the necessary amendments of the mental images, w*e, at the same time, unconsciously *strengthen those mental images which we are trying to amend.* Should we, thus, obey WITTGENSTEIN, who says "One must keep silent about things which one cannot speak of" and stop our trials to teach modern physics?

Time and space

The absoluteness of the speed of light is an empirical fact, which compels us to abandon the mental images of the absolute time intervals, distances and sizes. This leads inevitably to several predictions, which are complete nonsense from the point of view of the structure of mind bound to the primary perception, but which turn out to be correct in the empirical tests.

This empirical compulsion requires us to accept the *four-dimensional space-time* of special relativity as a more genuine representation of reality than our primary image of three-dimensional space, where absolute time is flowing. The sizes and distances of bodies do not qualify as representations of reality, because they depend on the observer. They are replaced by the observer-independent four-vectors, which we can no more master with our concrete mental images.

The conception of gravity as *curvature of the four-dimensional space-time* according to the *general relativity* puts our perceptual ability, if possible, to a still more severe test. This is nicely illustrated by a recent e-mail discussion on the dfcl-list[1].

[1] This e-mail list was founded, for information and discussion, on a two-years complementary education course of in-service physics teachers, started in 1996,. The course was titled dfcl (didactical physics cum laude), since according to the original commission of the National Board of Education the course should offer the "cum laude degree" in physics

The discussion was launched by a message of a teacher:
Today, on the school corridor I was asked a question: Where (in what direction) does the bending of space take place in the context of the curvature of space discussed in the theory of relativity. The students had considered among themselves, whether the space is bending in some new dimension or what. The problem is, that, according to our conception, the gravitational field is bending the path of light, and the books describe this by telling that the light goes straight (in relation to what?) but we observe a change of direction due to the curvature of space. I didn't quite know what to answer.

Excerpts from the responses:

Response 1 (A specialist in general relativity and cosmology):
"... "Curvature" means, that the geometry of space-time is different from the geometry of such a space-time which is not curved. …. there is no fifth dimension, to which it would be bent, not, at least according to the theory of relativity; curvature is just an internal geometric property of the space."

Response 2 (myself):
"... A 'surface-being', who is aware of two dimensions only, may observe in its surface-like world properties violating plane geometry. The sum of the angles of triangles may deviate from 180°, or the area of a circle can be not proportional to r^2. We, with our three dimensions, can interpret such properties of its surface-like space to arise from a bending of the surface towards the third dimension, either in a spherical or in a saddle-surface way, depending on whether the sum of the angles of a triangle is larger or smaller than 180° or whether the circle areas are smaller or larger than πr^2. The geometric interpretation as curvature is, however, beyond the immediate perceptual possibilities of the two-dimensional being, but, if he is mathematically clever enough, he can still call such observable properties of his surface curvature in an abstract sense. ... Time as a fourth dimension is still a different matter, because even a flat (non-curved) relativistic four-dimensional space is not Euclidean, as we perceive our three-dimensional space to be. Therefore, in that context, the mathematical concept of curvature is felt still more abstract by an order of magnitude."

Response 3 (An eminent mathematics teacher):
It does not bend anywhere or in any direction. This is just a manner of speech, due to the fact, that we perceive our living surroundings as an Euclidean space. The light ray takes the shortest (fastest) path and our way to perceive space makes the path to look bended. This is a similar type of phenomenon as in trying to find on a map the shortest flight route from Helsinki to New York. If we draw, on a plane map, a straight line from Helsinki to New York, it goes approximately along the boarder between England and Scotland and through Northern Ireland. On the basis of our mental images based on elementary geometry we may think that a straight line would yield the shortest route. This is, however, not the case, but the shortest path follows the arc of a great circle touching Island and the southern tip of Greenland."

The questioner: *"... In these questions of physics one often falls into this helplessness. At first, in teaching of classical physics, one emphasises the approach through basic perception, where everything should be understood right from the beginning, because no other understanding exists. Then one encounters these matters, for which the normal language has no concepts and for which one's head even cannot possess any real, correct mental images. The things can be described only by the language of mathematics, and even the teacher doesn't know this language sufficiently. The teacher bumps into this often, when he, at first, has succeeded in making the students to enquire and to question things …."*

The triumphal march of discontinuity

The classical mental images concerning the nature of time, space, entities and phenomena are characteristically continuous. One great main line of the development of modern physics is the gradual quantisation of the "elements of reality", replacement of the continuity by discontinuity.

Matter.
Quantisation starts from the matter. Discontinuous *quantised matter*, composed of atoms, enters the stage and takes the place of the continuous matter.

Atomic structure of matter has a long history. The main lines were sketched by HEIMO SAARIKKO on his fist lecture of this course. Even the history of scientific evidence about atoms is more than 200 years old. At the time of the F2k experiments, theoretical or *explanatory evidence* had been accumulating already for a whole century.

In 1803 JOHN DALTON predicted, on the basis of the atomic hypothesis, the chemical law of multiple weight proportions and confirmed this prediction experimentally, ending up with the first list of relative atomic

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on the basis of an "approbatur degree". After three successive dfcl-courses the list has continued as a conversation list , where the members have sent questions of their own and of their pupils for common consideration. The list is still alive and the physics teachers can join it by informing Ari Hämäläinen about their willingness.

masses. In 1809 LOUIS-JOSEPH GAY-LUSSAC verified the corresponding law for the volume proportions of chemically reacting gases, which was explained by AMADEO AVOGADRO in 1811 in terms of the molecular hypothesis.

The statistical mechanics developed by JAMES CLERK MAXWELL and LUDWIG BOLTZMANNin in eighteen sixties and seventies linked the thermodynamical state quantities to the mechanics of atoms and molecules. The idea was, however, rooted much farther back in time. Its pre-stage, the kinetic theory of gases, was launched already by the idea of DANIEL BERNOULLI in 1738, according to which pressure is caused by the impacts of the gas atoms on the wall of the container. The idea was given a quantitative representation in eighteen forties by showing that a gas of non-interacting molecules obeys Boyle's law. At the same time the concept of temperature derived back to the average kinetic energy of the molecules.

In 1824 LUDWIG SIEBER interpreted the crystals as ordered structures of atoms. In 1894 Sir KELVIN explained the crystal structure of solid matter on the basis of this assumption. In 1985 AUGUSTE BRAVAIS definitised this explanation in terms of the lattice structures known as Bravais lattices.

All this *explanatory evidence* concentrated on the structural properties of matter. At the change of century, it formed such a convincing whole, that it was considered compelling evidence even without direct *observational evidence.* Apart from few doubters, it was generally accepted that *matter consists of atoms!*

The atomic structure became, thus, in addition to the macro and micro levels, a *third level of treatment of the properties of matter:* matter as a particle system composed of atoms (and electrons). However, in the trials to explain properties of matter and their empirical laws on this basis, insurmountable difficulties were encountered. The theoretical predictions were wrong, often by several orders of magnitude, and sometimes even qualitatively senseless. The first clear indication of the crisis lurking behind the corner was Maxwell's statement in 1859 about the freezing of the degrees of freedom[2].

The first empirical evidence of the existence of atoms and the atomic structure of matter was obtained not until the X-ray diffraction studies by farther WILLIAM HENRY BRAGG and son WILLIAM LAWRENCE BRAGG around 1915. However, long before, the studies of even the structure of atoms had got off to a good start. As to the F2k-laboratory, the experiments of *Thomson* (1897) and *Millikan* (1911) were important preliminary steps. *Rutherford experiment* (1906 ... 1911) and *Bohr atomic model* (1913) were ordinary mile stones of it.

In this stage, at the latest, the atomic structure of matter was revealed as *"a young cuckoo in the nest of classical physics"*. It was the first representative of quantisation and its example was followed by the other elements of reality one after the other.

*Energy transfer***.**

The interactions of electromagnetic radiation with matter, *emission, absorption and scattering*, were the first to be thrown out from the nest. According to the classical mental image they should have been continuous by nature. Now it turned out, that they consisted of momentary and pointwise events. They resembled classical collisions also in the respect that energy, momentum and angular momentum were conserved in them.

In the F2k experiments this appears only somewhat obscurely in the secondary observation that charging of oil drops by X-rays occurs in sudden steps. (This note does, however, not apply to the F2k-version of the experiment where alpha radiation is used in stead of X-rays.) With the development of the detector technology this, however, became completely evident. The continuous fluorescence turned out to consist of momentary twinkles (scintillation), and the blackening of the film took place as accumulation of black points. The empirical compulsion to accept this discontinuity was obvious.

Quantisation of energy transfer in these interactions shows the momentary and pointwise nature of the interactions only somewhat indirectly. Still, *the black-body radiation* and *the photoelectric effect* are essential parts of the empirical compulsion for acceptance of the *photon as a quantum of energy transfer between electromagnetic radiation and matter in accordance with Planck's law.* This mental image is further strengthened by the explanations thus obtained for other phenomena. The X-ray *bremsstrahlung* was explained as a quantised emission and *Compton scattering* as a combination of quantised absorption and quantised emission.

A similar quantisation of energy transfer was seen to occur also in *mutual interactions of particles.* Freezing of the degrees of freedom, perceived in the specific heat capacities of solid substances, was the first indication of it. In the same way, as the spectrum of black-body radiation was explained by Planck's quantum hypothesis, the decrease of the specific heat capacities could be explained quantitatively by the assumption, that the degrees of freedom of lattice vibrations of solid matter can exchange energy only in *phonons,* i.e. in quanta hf proportional to the frequency of the vibrations.

Quantities.

Usually, "quantisation" is understood to mean quantisation of quantities. A quantity is quantised, if it can take only some definite discrete values. There are quantised quantities also in classical physics. The *number* (the quantity representing the size of a discrete set) is an obvious example. Natural numbers are its possible val-

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[2] See lecture 3. "*The F2k experiments 2."*

ues. The *frequency of a vibrating system* is another one. Its possible values are called eigen-frequences of the system.

In modern physics we are forced, by empirical compulsion, to accept that many quantities, which are continuous in the classical theory of physics, are in fact quantised. The atomic structure of matter meant quantification of the *mass* of bodies. The Millikan experiment showed that *electric charge* is quantised. *Transfer of energy, momentum and angular momentum* is quantised in the interactions. But when speaking of quantisation of *energy*, we think, in the first place, the total energy of an atom or, more generally, of an atomic system. The empirical compulsion for the acceptance of its quantisation arises from line spectra.

The optical line spectra[3] turned out to be characteristic to the atom or molecule species. Thus, there was an obvious explanation available for the line frequencies as eigen-frequencies of vibrating systems. The systematic of the line frequencies was, however, totally different, and it was not possible to find, on this basis, any explanation based on the structure of atoms. Moreover, the momentary nature of emission and absorption fought against the idea. *Ritz' principle,* with *Balmer's law* of the spectrum of the hydrogen atom as an example, offered an empirical basis. Its obvious interpretation in terms of Planck's law was a strong indication of atomic stationary states, with definite energies characteristic to the atom. When, finally, the experiment of *Franck and Hertz* offered an independent confirmation, the empirical compulsion was ready.

Discontinuity of the existence and the loss of individual identity

This title involves a set of difficult mental images, which require heavy amendments of the classical imagery about the elements of reality. They drive the ontological crisis into its culmination.

Wave-particle dualism.
The basic empirical starting point is the so called *double-slit experiment.* This experiment is not included in the repertoire of the F2k laboratory. All participants, however, know it well in principle. The F2k experiments are, however, tightly linked to the same empirical whole. Interpretation of *line spectra* as the empirical key to the atomic structure is already riding on the new mental imagery. Otherwise, the F2k experiments are preliminary steps in the development of the empirical evidence compelling us to adopt the new mental images. Particularly, they are of decisive importance in bringing the electron and the photon into consciousness as new objects of research. For both of them, the double-slit experiment leads to an abrupt contradiction with the classical imagery. The classical mental images of particle and wave motion must be abandoned and a completely new idea about the nature of the basic entities and phenomena must be developed.

The experiments of Thomson and Millikan lead to the mental image of electrons as a sub-atomic constituent of matter. They, however, don't hint in any way, that the electrons would be anything but particles in the sense of the classical mental picture.

The black-body radiation showed that energy transfer was quantised in the interaction of radiation and matter. This together with *the photoelectric effect* made Einstein to adopt the concept of photon. Einstein, however, treated the photon as a classical particle and, like Newton, light as a photon beam. The success of Einstein and the complete failure of the classical wave model, in explaining the photoelectric effect, lead to a severe internal contradiction in the understanding of light, since diffraction was understood to be a binding proof about the wave nature of light. Even Newton had given way in the face of this "empirical compulsion"

Finally, the double-slit experiment, which is still to-day repeated again and again for new kinds of particles, offered the possibility to clarify this problem. There, the particle and wave properties of radiation occur at the same time in the same experiment, regardless of the radiation studied. The *diffraction pattern*, the binding proof of wave nature is observed, but it is created by accumulation of *"single hits" characteristic to particles*, even when the radiation is so weak that "hits" occur one at a time. This empirical observation is called wave-particle dualism.

Einstein, in his interpretation, had "exceeded his powers". The empirical evidence of the black-body radiation and the photoelectric effect concerns only the quantisation of energy transfer according to Planck's law. It does not offer any empirical basis for the concept of photon separated form the energy transfer events.

The same is, however, true for all observations of diffraction. On the basis of the double-slit experiment it is obvious, that any diffraction pattern consists of single "hits", although no attention had been paid to it earlier in the considerations of the nature of light. On the other hand, at the time of the decisive historical diffraction experiments, there would not have been any technical possibilities to observe it. Neither is it justified to speak of light, separately from the observed diffraction pattern, as wave motion.

Discontinuous existence.
There is, thus, no empiry-based internal contradiction in the wave-particle dualism. The contradiction is just between two interpretations. *Particle beam and wave motion* or *two classical mental images, models,* trying to explain what is observed on the screen or in the detector. The question, *whether the electron and the pho-*

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[3] See lecture 3. "*The F2k experiments 2."*

ton are particles or wave motion", has equally little sense as the suggestion: *"Electrons and photons occur sometimes as particles and sometimes as wave motion, depending on the experiment used in observing them."* In the double-slit experiment the characteristics of both natures occur at the same time in the same experiment, and, on its basis, neither mental image can serve as presentation of the reality. But what instead?

The two laws presented by LOUIS DE BROGLIE in 1924 express accurately the relation, which arises between these two models, when they are used to represent the same phenomenon. These laws offer also the starting point for the concept of *wave function* in *Schrödinger*'s formulation *of quantum mechanics* and for building the necessary new mental imagery.

The double-slit experiment sets the photon and the electron on the same starting line! At the same time, all other basic entities of nature step beside them. In order to say anything more about their nature, it must be realised that the empirical compulsion arising from the double-slit experiment does not allow acceptance of anything but *momentary and pointwise events* as basic elements of existence. Everything, what is said beyond that, is interpretation, which must be amended in front of the empirical compulsion. This means, that, on empirical basis, there are *no continuous phenomena, not even any continuous existence.* And, if there is no continuous existence, neither particles nor wave motion can exist in the sense of the classical imagery. At the same time the bottom falls under the *deterministic causality*, governing the classical mental imagery, particles as well as waves. The interpretation of the double-slit experiment, in terms of the concept of wave function, offers an idea for a probabilistic treatment of the occurrence of momentary and local events.

The identity crisis of particles.

When, after all this, all fundamental entities are called commonly "particles", one must understand, that the word has been given a new modern meaning, decisively different from the classical mental image of a particle (cf. the previous lecture). The (modern) particles get "realised", i.e. they appear into the "reality", only in the momentary and local events, which look like hits and collisions of (classical) particles.

This leads to the *identity crisis* of particles. The momentariness of existence destroys even the possibility of an individual identity. And, without individual identity it is impossible even to ask *"Am I the same individual as a moment ago, or a different one*", because "I", "same" and "different" involve the idea of individual identity. Similarly, the question: "Is this the same particle as a moment ago, or a new one" has no sense.

All what is left to any entities is their *species identity*. The particle species have their characteristics, which make possible identification of a particle as a specific kind of particle, electron, proton, photon, pion, … Lack of individual identity means, that all entities of the same kind are mutually *identical*.[4] This is an awkward mental image, because identicalness means sameness in a much deeper sense than similarity of, for instance, identical twins. There are *Z* electrons in the electron cloud of an atom, but it is not possible to individualize them. They are "the same electron Z times", or how could one express it. We can't get forward from this without introduction of the idea of quantisation of fields.

Quantization of fields.

Quantisation of fields, or rather the state of being quantised, refers to the state of affairs, that even the fields as entities are not continuous. The theoretical step taken in the transition from the continuous-field model to the quantised field, is also called *"second quantisation".* This wording refers to the fact, that the transfer from classical mechanics to Schrödinger quantum mechanics was only a partial "first quantisation". The quantities representing the dynamics of a particle system were quantised, but the fields were still treated as continuous entities in terms of the classical potential functions. The resulting model, however, explained a.o. the quantised energies and angular momenta of atomic systems, quantitatively very accurately, and it brought us very far in the physics of atoms and molecules.

As a whole, the situation gets clarified not until also the fields are quantised. This measure is not a mere quantisation of the classical fields, but it refers similarly and equally to all "particles".

As the starting point we can take a mental image, where for each entity species, electron as well as photon, there is a corresponding "species field". The quanta of this field appear as particles of the species, in the same sense as the photon appears as the "particle" of the electromagnetic field, which now takes the position of the species field of photons. Each species field can be characterised as a "field of potential occurrence" of the corresponding particle species, covering the whole space. Realisation of the particles occurs only as momentary and local events. We are, thus, back to the final brain teaser of the second F2k introductory lecture.

As quanta of its own species field all particles of the same kind are identical, they all have the same species identity determined by the field. In a way, the field is considered as a system of many identical particles, where, however, the number of particles is *a priori* arbitrary. When this kind of a system is described in terms of a wave function, the identicalness means, that exchange of the "coordinates" of any two particles leaves the observable meaning of the wave function unchanged. This involves, in principle, two possibilities. The

[4] Note here the implied difference in meaning of the concepts "identity" and "identicalness".

wave function either stays unchanged or it changes the sign, in other words, it is either symmetric or antisymmetric in respect to all particle exchanges.

Fermions and bosons.
Symmetry and antisymmetry lead to completely different properties of the field or the many-particle system. Particularly, as a consequence of antisymmetry, any specified "one-particle state" can be occupied by, at most, one particle at a time. Symmetry, again, does not cause any limitations in this respect, but a one-particle state can hold, at the same time, any number of particles.

Each alternative is realised in nature. For me, this is one of the most marvellous examples of the power of mathematical representation in physics. All particles divide into two classes, *fermions* (antisymmetry) and *bosons* (symmetry). *The fundamental constituents of matter*, electrons and nucleons (more generally, leptons and baryons) are fermions. Photons and other *transmitters of interactions are bosons*.

The empirical evidence of this division arises, above all, from realisation of predictions deriving from the antisymmetry and symmetry. This grows in nature into enormous measures. The antisymmetry represented by the fermions appears, particularly, as Pauli's exclusion principle, responsible for the existence of matter and for the whole abundance of chemical substances and the consequent richness of the material world. The symmetry of bosons appears a.o. as the so called Bose condensation, accumulation of large numbers of particles in one and the same one-particle state. Also the macroscopic appearance of light as wave motion can be understood as a consequence of the boson nature of photons. The wave function of a one-particle state, or rather the corresponding probability distribution, is "realised", when an immense number of photons occupy the same state. The corresponding "realisation" of an electron state is not possible. It can succeed only by forcing one electron at a time to "settle" into the state considered and by repeating the experiment vary many times (as in fact happens in the double-slit experiment.)

In the quantisation of fields the number of particles is a dynamical variable beside other quantities. Natural numbers are its possible values (eigenvalues). It turns out that, as a consequence of antisymmetry, the eigenstates of the total energy of a fermion system are also eigenstates of the number of particles. In other words, the number of fermions in an isolated system is fixed. The symmetry causes, to the contrary, that the number of bosons is not fixed. Particularly, the "number" of photons in the field varies. Photons are appearing and vanishing all the time. Their number has just an energy-dependent probability distribution.

Understanding the number of particles as a dynamical variable may offer some help in the linguistic problem, which is met when trying to speak, for instance, of the electrons of an atom. There is a permanent fixed number Z of them, which can be determined experimentally. But there is no empirical evidence about the existence of individual electrons in the atom.

In this way the empirical starting points of the classical mental images of particles and fields, or particle beams and wave motions, have an explanation based on the properties of fermion and boson systems. The fermions and bosons are the modern heirs of the classical particles and fields, respectively.

Ontology of discontinuous existence

Replacement of the continuity of phenomena by momentary and local events, and the consequent limitation of the existence of entities to these events, is one of the most difficult mental images of modern physics to perceive. Trials to describe the mental image of a "twinkling reality", thus arising, enlighten in an interesting way the linguistic problems involved in speaking of modern physics. How to speak of particles, the existence of which is restricted to momentary local events only?

Leaning upon our classical mental images we can imagine the events to be momentary occurrences of particles in mutual interactions of their species fields in a way, which resembles collisions (or other momentary particle processes.) This mental image gives us the possibility to classify these events as if they were collisions or "births" and "deaths" of particle individuals. The *quantities measurable* in these contexts offer, on the basis of the conservation laws, which now are raised into the position of postulates, the possibility to interpret the totality of these events in terms of a set of particle species characterised by certain particle properties.

It is true, the "particle orbits" observed in cloud, bubble or spark chambers, yield an apparently quite justified mental image of continuous orbits of continuously existing particles, obeying the known laws of physics. But the "orbits" consist of successive events, and it is rather easy to verify, how the conservation laws are responsible for this apparent unity and law-obedience of these "orbits".

Speaking of "collisions", "births" and "deaths" when describing the momentary events, is language tied to the continuous existence of the macro world. In a collision two continuously existing entities meet and separate again. "Birth" is the start of a continuous existence, and "death" is the end of it. But how else would it be possible to speak of these events.

When there is no continuous existence, there are no individuals. Even within the interpretation it is possible to speak of the species only. In each event, two (or more) species pop up simultaneously for the vanishing moment of the event. We call them interaction events. But also "interaction", "event" and "simultaneity" are words, which hide the idea of continuous time and continuous existence perceived in our macro world. "Interaction" is interaction of two continuously existing entities. The "event" has a moment of time in the continuously flowing time. It involves a mental image about the preceding and succeeding time flow.

A parallel problem occurs in the popularising talk of the "point" of "big bang". The word "point" involves inevitably a mental picture of a surroundings, where the point has some location and negligible size as compared to the surroundings. But, what would be the sense of a "point", which in itself is the whole universe without even a possibility for surroundings. Similarly, what sense could have a "moment", which wouldn't be a moment (of negligible duration) in the continuous flow of time, or "simultaneity", if there wouldn't be also time differences of two moments in the time flow.

In this way, talking of particles and interactions is a (just) mental model for interpretation of the events. Again, we have here a metaphysical interpretation, which has just the value of an interpretation without any evidence arising from empirical compulsion. And this interpretation is essentially founded on the idea of continuous existence, i.e. on an idea, which, in itself, contradicts the reality to be described by it.

It is true, this mental picture is, as is the whole classical mental imagery, tremendously important as a unified representation of the phenomena. It can be called "standard model", or what ever other model, which enables classification of those fictitious entities, with continuous existence in our imagination. But, what remains as the true continuous existence, is just the possibility of occurrence of all particle species represented by their species fields, the fields of potential existence.

Appendix: Questions of a student

The questions, upon which I have been pondering in this lecture, are far beyond the range of the official physics curricula. But the teacher cannot avoid them. As an example I am appending an extract of a recent student's question on the dfcl-list (see footnote 1), plus the relevant main points of my reply.

> Student:
> *"How does the photon transmit the electric and the magnetic interaction?... How does the magnet send photons, and how do the photons transmitting the attraction and the repulsion differ, and why don't the photons of electric and magnetic interaction get mixed? The teacher told, that, perhaps, the spin of photons has something to do with this. What, actually, does the spin describe? Feynman's path integrals and Heisenberg's uncertainty principle I know as ideas. Perhaps, they also have something to do with this."*
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> Main points of the reply:
> *"Commensurate description of the field model and the carrier model of interaction is not easy in such detail. Your questions bring us deep into the odd mental imagery of modern physics, where the empirical results compel us to abandon the safe concrete mental pictures of classical physics like individuality and continuous existence of particles … and the continuous course of phenomena gets reduced to momentary and local events. …"*
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> *"The photons 'get realised' only in interaction events of electromagnetic radiation with matter, i.e. with charged particles …. The photons are not … individuals with continuous existence. They are quanta of energy, momentum and angular momentum transmitting in momentary and local events (emission, absorption)… It is true, these events evoke a strong, even quantitatively very clear, mental image of appearance, collision and disappearance of photon particles. It belongs to this mental image, that a photon has the energy hf, momentum hf/c and spin 1, directed either forward or backward,. ... These quantities transmitted in such "doses" form, however, the only observable reality. The photon particles themselves are just fictitious explanatory models.*
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> *Here, momentum is the element, which can be understood to represent the electric interaction, and spin (angular momentum) the one, which represents the magnetic interaction. From them, all different alternative kinds of the electromagnetic interaction follow. There are neither any separate photons of attraction and repulsion nor electric and magnetic photons."*
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> *"Charged bodes and magnets do not send photons. The static fields can be understood as (probability) distributions of "virtual photons". Photons can be thought to be degrees of freedom of these fields. Virtual photons are a kind of "zero-point vibrations of these degrees of freedom below the limit of observability set by Heisenberg uncertainty principle. Still, these virtual photons, appearing and again disappearing before they can be observed, affect the object particles on the position of their appearance and disappearance in a way, which is observed as electric and magnetic forces.*

"Spin is a kind of "rotation quantum", however, without any rotation which could be represented by an angular variable. It appears only as an angular momentum, which, as a whole, is conserved in the interactions of particles. It resembles rotation also in the respect, that, in the case of charged particles (or particles with a charge structure), there is always a magnetic moment linked to it.

" Feynman path integrals are a field theoretical way to represent interaction events of particles as a combination of all possible "interaction paths". Also the interaction of photons with material particles can be represented in terms of them, but, to my understanding, this doesn't throw any further light to the problem of separation of the electromagnetic interaction into the electric and the magnetic interaction. They are linked to my clarifications above mainly in the way, that all intermediate stages occurring on any Feynman path are 'virtual particles'."