ON PHYSICS

http://unism.pjwb.org
http://unism.pjwb.net
http://unism.narod.ru

Assorted notes clarifying the position of unism in physics were written in 1983–2007. They are presented here without any particular order, just as the drafts were formatted for publication. The selection favors brief notes of a philosophical character. Too technical papers containing many equations and calculations have been intentionally omitted.

On Virtuality

Local quantum field theories were the basis of high-energy physics in the XX century. Any such theory postulated some symmetric and covariant expression, which, according to the principle of minimal action, would describe all the variety of physical effects allowed by the model. In earlier days, this model action was used to derive the equations of motion, and a number of exact solutions have been obtained for simple cases. However, many-body equations could never be solved exactly, and approximations were necessary to obtain practically usable results. Numerous approximate models were built in all the areas of quantum theory, from atomic physics, to quantum gravity. Some of them invoked phenomenological elements; more "rigorous" theorizing largely exploited the standard technical trick, successive approximations. The perturbation-theory approach splits the full action into two parts, one of them describing a simpler system with already known physical properties, and the other part treated as a small correction to the "zero-order" behavior, so that the motion of the "perturbed" system could be expanded in a power series: in the first order, perturbation couples the elements of the simplified system just once, the second order terms account for the possible double couplings, and so on. As diagrams were invented as a convenient technique for constructing all kinds of perturbation series, equations of motion have gradually come to a deep neglect, while approximate solutions can be immediately obtained using the form of action, without deriving any equations of motion. Physicists went in for computing higher-order diagrams, and nobody much cared for the original strongly coupled theory, without separating zero-order action from perturbation.

There was a price to pay.

Thus, perturbation series utterly refused to converge, producing infinite values in all the orders above the very first. For most fundamental interactions, the perturbation was not small, so that the series could only be considered as asymptotic. Infrared and ultraviolet divergences haunted quantum field theory from the very beginning; many ingenious tricks were invented to overcome this difficulty and obtain finite solutions. Physicists learned to "renormalize" the theory up to any given order, removing all the divergences. Perturbation theory has been complemented with renormalization theory, and the best we can expect is to prove that our theory is renormalizable to any finite order. A fine new criterion of physical sense!

Second, physicists got accustomed to treating successive approximations as the only way to describe physical reality; they just cannot think but in the terms of perturbation theory, interpreting all the natural phenomena from that angle. Mathematical tricks take the place of physical reasoning, with various artificial constructions presented as the true picture of the physical world. This is how the idea of a virtual particle has penetrated science.

In any order of perturbation, the expression for the transition amplitude (or any other appropriate quantity, like *S*-matrix, *K*-matrix, propagators, evolution operators, density matrix *etc*.) takes the form that can be formally interpreted as a superposition of all possible transitions from the initial to final state via a sequence of intermediate states, coupled to each other by the perturbation. The intermediate states do not need to preserve the energy (or any other quantum numbers) of the initial and final states. This means that it is only the initial and final states that can be considered as *physical*, in the sense that they have the correct symmetry and obey conservation laws; the intermediate states are free to violate the physical symmetries and hence they will be unobservable, that is, *virtual*. For instance, in atomic scattering, an unbound state of the system (target + projectile) may exhibit a complex resonance structure due to formation of virtual bound states "embedded in continuum". From the perturbation-theory viewpoint, this can be interpreted as temporary formation of a compound particle from two incident particles (target and projectile), followed by subsequent dissociation into the original (or some other) set of particles. That is, the number of particles in the system may change from physical to virtual states and between virtual states. In quantum field theory, the same technique applied to gauge fields (and primarily the electromagnetic field in quantum electrodynamics) lead to the picturesque idea of the physical vacuum as a sea of virtual massive particles born and annihilating back at any moment. This picture of particles popping out "from nothing" and disappearing "into nothing" is a perfect source of inspiration for idealistic philosophers and theologians, as it provides enough room for spiritualism in-between the acts of spontaneous birth/decay. The apparent violation of causality in the virtual states is easy to attribute to the will of a deity, or any other existential abstraction of consciousness.

However, such virtual particles are nothing like true particles, but rather an artifact of a specific computation technique. Yes, such abstractions are helpful in solving complex physical problems, as they may lead to practically acceptable results. Still, at least in principle, the same results could be obtained in many other ways. Thus, perturbation-theory expressions usually involve summation (integration) over all the intermediate states assumed to form a complete set. It is well known, that one can always choose a different basis set for such a summation, without influencing the results. For instance, there are mathematical tricks that replace a continuous spectrum of intermediate states with a discrete set (Sturmian expansions); such intermediate states can hardly be interpreted in terms of any physical fields or particles. This illustrates the absurdity of putting too much confidence in the vulgar descriptions of physical processes from the perturbation-theory viewpoint. Such figurative explanations are necessary to visualize the abstract mathematical procedures, thus rendering them more tractable; however, they do not necessarily correspond to any physical reality, no more than the complex conglomeration of rods and wheels invented by Maxwell to visualize his theory of electromagnetism.

From non-perturbative solutions of the equations of motion, one can obtain the same complex structures as in the perturbation-theory scheme, but without any need for virtual states or particles. This approach is physically attractive, and it has been widely used in atomic and molecular calculations (the so-called "close coupling" approach). Unfortunately, in many cases, we just cannot derive the equations of motion, and even if we can, their direct solution for many-body systems with variable number of particles is practically unfeasible. That is why we will always need perturbation theory, but as a mere computation tool rather than the language of explanation.

While the picture of virtual particles as independent entities is basically unphysical, there is a more adequate idea applicable to the description of complex structure formation in physical systems due to *collective effects*. It is well known that the dynamics of nonlinear media can result in various shapes existing for a long time, and eventually dissipating (like phonons, solitons *etc*.). In this view, resonance spectra observed in quantum physics can be explained as quasi-stable collective modes of motion in many-body systems. The system moves *as if* there were virtual particles or states, though this resemblance can never be complete. Quantum states are determined for the whole system, and they evolve according to the system's equations of motion; however, for some time, the structure of the state can resemble a collection of distinct particles coupled by relatively weak interactions. When the lifetime of such dynamic formations is much less than the characteristic time of system evolution, we speak about virtual particles. As long as external fields remain weak as compared to the system's inner interactions, they do not resolve individual "virtual" structures, and all we see is their combined effect (resonances). However, a strong external field can penetrate a virtual structure, transforming it into an observable entity. For instance, a drop-like bulge can be formed at the mouth of a water tube; it may vibrate, or change its size and shape for some time, still joined to the rest of the water in the tube; then gravity or mechanical shock will complete the formation of the falling drop. In this sense, one can say that virtual structures are *incomplete* structures, or quasi-structures. Obviously, their incompleteness is determined by their relation to the whole: virtual structures are always *substructures* of something better coupled. In physics, we usually deal with abstract quasi-closed systems that can be deemed to be structurally complete; their substructures, in general, will be virtual, in the physical sense, regardless of the formal representation. Reality and virtuality are well separable on this level. However, in a wider scope, any possible structure can only exist within the same and only world, and everything could be considered as virtual in certain respects, when we are not interested, for a while, in its connectedness to the rest of the Universe.

13 Feb 2007

Remarks on F. J. Tipler

Recently, we have witnessed a wide discussion of Frank J. Tipler's conception of life in a collapsing universe, near the *Omega Point*. Putting aside the fantasies about gods and resurrection, one could just wonder if there were any real problems that might stand behind all that noise, with something worth consideration still requiring a more appropriate expression.

As far as I can see, most speculations of that kind grow from the uncritical physicalism in the treatment of matter, energy, space and time, evolution and development, life and reason. Of course, a scientist may play with theoretical models, and apply any special concept to almost anything. However, if, in this way, we come to obviously absurd conclusions, the first thing to do is to adjust the unreasonable model, rather than to put on airs and sell these absurdities as the final truth. Most people are aware of the fact that physics is *not* well suited for studying psychological phenomena and life; it even fails to provide a complete description of chemical processes. The very existence of different sciences is an evidence of some difference in their object areas. Consequently, a comprehensive scenario of universal evolution based on yet another physical analogy can only be useful as an illustration of the formalism, or as an attempt to get across the limits of the theory's applicability in a deliberately inadequate extrapolation.

Many bright scientists were fascinated by their profession to the degree of losing the view of the difference between a formal model of reality and reality thus approximated. This disease is most frequent in fundamental research, like general relativity or quantum field theory. I admit that mathematical tricks can be a most exciting entertainment; still, such formal manipulation will remain entirely meaningless until we discover its true sense in practical activity. Mathematicians like talking about "rigor" and "proof"; some philosophers uncritically joined in with the tales like "verification" and "falsification". In real life, nothing can be "proved" beyond doubt, since any proof needs some preliminary assumptions and a kind of traditional logic; the both premises are disputable and subject to historical development. The products of formal deduction do not need to be true, and conversely, some truths come from practical acts beyond formal reasoning; in the XX century, this circumstance has come to the public awareness in a limited way, through the mathematics of computability.

Well, assuming that far extrapolations of Tipler's (or Dyson's) kind illuminate the limitations of the contemporary science and thus express the necessity of a new conceptual basis, let us list a few open questions that might inspire Tipler, regardless of the level of awareness.

1. *Insufficiency of the physical description of space and time*. The ideas of space and time refer to the *development* of the world, while modern physics is largely based on the traditional "coordinate frame" paradigm, picturing space-time as an entity existing before any physical events to be put in. General relativity pretended to bind the structure of space-time to matter, but from the very beginning, this good intention was compromised by geometric reductionism; modern physics generally follows the inverse logic, trying to deduce matter from geometry, which is a sure way to a dead end.

2. *Too vague awareness of the hierarchical organization of the world*. Most people admit that life is a little more than mere physical motion, and that conscious activity is somewhat different from mere

organic life. However, the nature of this difference remains unclear. This provokes stubborn attempts to reduce one level of complexity to another, deriving higher forms from the most primitive, or conversely, bringing all kinds of motion under conscious control. However, life can never be explained by physics and chemistry, though it is impossible without certain physical and chemical processes; on the contrary, life tends to modify the physical environment in a way that can drastically change the character of physical motion. Similarly, subjectivity is *accompanied* with biological or physical events, but they do not explain it. A conscious action can interconnect natural phenomena of any kind, rearranging physical and biological processes to adapt them to cultural needs.

3. *No clear recognition of the place of subjectivity in the world*. Modern science and most philosophies have not yet come to comprehending the necessity of reason as an objective stage of natural development. This drives scientists either to rejecting the very idea of subjectivity, or to reducing it to vulgar arbitrariness, or sometimes, to declaring it to be something beyond human comprehension and virtually beyond the physical world (that is, a kind of god). Tipler's approach is a mixture of these trends, replacing conscious beings with mere computers deciding between many random destinies under the rule of their Omega-god.

The Logic of the Paradox

The issues related to the nearly century-old the EPR paradox have recently been reported to find some experimental foundation. However, a closer examination of the experimental techniques and setup reveals a number of serious conceptual difficulties that are still far from being resolved. While there is no decisive experiment, any theorizing is to stick to the conceptual level, without really asserting or denying anything.

I suspect that an experiment that could bring light to the EPR problem is impossible in principle. Such issues do not belong to the physical domain, and even to the realm of science in general; they are the bread of philosophy and methodology. Encountering a paradox, one can be sure that there is a logical fallacy, with the different levels of hierarchy treated on the same footing, confused in the same discourse. As soon as we clearly discern the viewpoints involved, any contradictions will disappear. The logical aspects of the EPR discussions could be summarized as follows.

1. Any theory is only valid within the limits of its applicability; there are no absolutely "rigorous" studies in science. That is, the adequacy of a physical theory is not a matter of formal derivation, there are no "theorems" and "proofs", since the inadequacy of the theory beyond the limits of applicability is anticipated from the very beginning, before any formal justification or experimental tests. Maximum of what one could achieve is deriving some applicability conditions (usually in terms of strong inequality), and this could only be done in the framework of a more general (higher-level) theory. As no fundamental generalizations of quantum mechanics have been suggested, any talk about the conditions of its applicability will remain sheer philosophy, and the suggested formal criteria (like Bell's inequalities) have no scientific sense. Even if some experiments confirmed their strict validity, this would tell nothing about the limitations of quantum and classical pictures of the world.

2. One could indicate that many conceptual difficulties of quantum physics come from its logical incompatibility with relativism. Quantum mechanics and relativity extend classical physics *in the opposite directions*. In the relativistic approach, the observer is very small, and all he can observe is his immediate environment; relativistic physics is essentially local, it cannot compare spatially separated events. On the contrary, the observer of quantum physics is supposed to be infinitely big, viewing a quantum system from far apart (mathematically, from infinity), so that the parts of the system cannot be discerned. Thus, one can detect particles (or waves) moving to and from the system at infinity, where they are no longer belong to the system of interest; in any case, there is no way to track the history of the interactions of these particles with the individual components of the system (atoms, molecules *etc.*). As long as an electron is treated in a quantum manner, we cannot know whether it has come from an

atom in the experimental device, a sun flare, or a distant galaxy; there are no *individual* electrons in this sense.

Obviously, simultaneously being both small and big is a nontrivial task, and all the relativistic quantum theories have to seek for a kind of trade-off. They are inherently inconsistent; however, no science (including mathematics) can be entirely consistent, and this does not much matter, since one can always switch to another theory if the old one does not work well enough. Science thus acquires an element of art: a scientist has to find a delicate balance between the different models, to obtain a meaningful result. When such a balance is achieved in a clear and economical way, we speak of scientific beauty.

3. From the relativistic standpoint, there can be no action at a distance. If two electrons are far enough from each other, they *can* be distinguished, and anything happening to one of them can bear no influence on the other. This is an entirely "macroscopic" picture, meaning that each electron enters only macroscopic (uncorrelated) interaction; in that case, there will be no exchange effects and no need to introduce "quantum telepathy", and no paradoxes. For example, electrons behave like plain macroscopic particles in Millikan-like experiments, in Geiger counters, in industrial electron beams…

In the opposite case, on the "microscopic" level, the particles (or fields) interact with each other so that only the macroscopic (well separated from the quantum system) products of this interaction can be observed. Now, the electrons are completely indistinguishable, in the sense that you cannot selectively act on an individual electron and have to consider the probability of acting on one electron or another. Again, there are no conceptual problems.

Mental experiments of the EPR type illegally combine both macroscopic and microscopic description, which takes the form of an apparent contradiction, a paradox. This has nothing to do with physics, but rather with the inconsistency of the model lumping together physically different phenomena.

4. Quantum mechanics is philosophically attractive since it seems to advocate the idea of an essentially holistic universe. But it does not. On the contrary, the quantum approach splits the whole world into two worlds formally opposed to each other, macroscopic and microscopic levels; this distinction is absent in classical physics, which can therefore be considered as more universal. The broken integrity leads to conceptual difficulties and calls for metaphysical speculations to restore the holistic view.

Relativism breaks the universality of classical physics in yet another way, admitting that some parts of the world can be physically separated due to the final nature of the speed of light.

The elimination of the inherent contradictions in both quantum physics and relativism will be possible in a more general theory synthesizing the traits of the both rather than eclectically mixing them like in quantum field theories.

Quantum Nonlocality, Stellar Evolution and the Integrity of the Universe

Quarks and leptons could be considered as essentially nonlocal objects, a kind of collective effect. Thus, in the simplest case, in an electron-positron pair produced by an energetic photon, the two particles would presumably bear the touch of their common origin and move in sync during their lifetime, as if they were the opposite ends of a string; this string would have its oscillation modes observable as gauge fields. A more complex system would be similarly pictured as an ensemble of many particles, with many connecting "strings", assuming multiple "oscillation modes". The observable interactions reconnect the "strings", revealing some other collective modes, but do not change an underlying sea of particles.

Normally, once established, the connections between the particles in a group will always be preserved (accounting for possible rearrangements), just because the relative velocities of the particles can never be greater than the speed of light. However, one could also consider *essential nonlocality*, when correllations between the particles get established through space-like intervals due to specifically quantum effects, like those assumed by the Bell theorems. In this case, the connecting "strings" would become virtual, that is, their oscillation modes (associated with elementary particles and gauge fields) would be not observable; this could explain the purely virtual existence of quarks and gluons. Quantum links of this type could also be responsible for the processes of macroevolution in the Universe.

Thus, one might suspect that matter in the stellar cores (and in the central regions of other massive objects) should be much more correlated than in relatively rarefied forms observed in the outer shells of the stars and in the outer space (including planets). Within the stars, elementary particles do not necessarily behave in the ordinary way, much like an atomic nucleus is not a mere combination of protons and neutrons, but rather a complex superposition of the both. In quantum chromodynamics, a nucleus is treated as one extra-heavy elementary particle, a collective state of many quarks and gluons; similarly, one could fancy something like a quark star. In the assumption that at least some quarks of a stellar core are connected to the quarks inside other stars by virtual “strings”, the processes in distant stars can be synchronized, and the evolution of one star thus becomes dependent on another. The collective oscillation modes of such “macrostrings” could influence the evolution of individual stars as well.

With all that, one could seek for different forms of evolutional synchronicity. The direct evidence would come from various correlated periodic processes (say, synchronized pulsars). On a larger scale, the phases of stellar evolution may be controlled by the states of the neighboring stars, or even the overall state of the Universe as a whole. The regularities of stellar distribution in space could be explained in that line, including the possible origin and typology of galaxies. In any case, the picture of the stars connected by virtual “strings” and developing in sync provides more room for theorizing than a simplistic picture of randomly scattered stars evolving on their own.

A fundamental corollary from the concept of interconnected Universe is that the development of the Universe must be correlated on all the levels, up to life and reason. The appearance of life in some part of the Universe is in no way random, being prepared by the processes of macroevolution. In the same way, when life develops to the level of consciousness, this will be interpreted as a manifestation of the universal integrity. Moreover, the very ability of human reason to grasp phenomena incomparable in scale to the bodies effectuating a specific form of conscious existence might be attributed to quantum interconnection between very distant parts of the world, consciousness being just a higher-level form of collective motion, a kind of eigenstate of a “superstring” connecting the whole Universe into an integral world.

28 Sep 1998

EPR Experiment and Complementary Paradigms in Physics

Since Einstein, Podolsky and Rosen have published their famous paper in 1935, there has been much speculation around the thought experiment they suggested to illustrate the issues of compatibility between quantum theory and relativism. The problem is certainly nontrivial. There are many relativistic theories of quantum systems, and, in a few cases, such theories allow rather accurate predictions. However, we are still far from a consistent theory incorporating both quantum behavior and relativism in a logically satisfactory way. To proceed, any doubts are just “swept under the carpet” and all we have is mere *a posteriori* justifications comparing the results of calculations with experiment. This would cause no problems for a semiempirical theory, but a fundamental science cannot stop seeking for a uniform description of phenomenological diversity, which would provide the formal criteria of the theory's applicability.

With time, discussions around the EPR experiment have outgrown the scope of a specifically physical problem and induced an extensive philosophical controversy related to the methodology of science and mind-matter relations in general. The numerous interpreters brought the ideas underlying the EPR-type experiments to the wide public, incidentally promoting various ideological distortions and utterly unphysical visions; today, it may be difficult to restate the problem in a scientifically productive manner.

A few examples of common prejudice around the EPR experiment and the relationship between quantum and relativistic paradigms are presented below.

Prejudice 1: *Classical mechanics differs from both relativity theory and quantum mechanics in that it treats physical systems as independent of the observer, describing them in the absolute terms.*

This is a misconception. No science can deal with isolated things, regardless of their participation in human activity. Formal structures developed in science reflect the common ways of our operating with things, and hence they always refer to the fragments of nature that have already been involved in cultural processes, and primarily, in industry and agriculture. A scientific concept is a concentrated expression of a scheme of activity, which entirely determines the scope of the concept's applicability. Consequently, any theory is bound to incorporate a model of the subject of the underlying activity. In classical mechanics, such a model is provided by the concept of *frame of reference*. The Galilean principle of relativity states that all the *inertial* frames of reference are equivalent in respect to dynamics, that is, mass, acceleration and force; the observers that move with a constant speed in respect to each other will see the same physical picture. This means that each observer must be large enough to correlate different spatial points *at the same time*; more specifically, the observer is said to be able perceive the state of all the objects within the frame of reference "at a glance"; on the other hand, the observer must be small enough to be able to discern the details of the system, individual bodies constituting it. Roughly speaking, the size of observer must be comparable with the size of the system observed.

Alternatively, one could consider a frame of reference as a continuum of observers located in different spatial points, on the condition that the speed of communication between observers would be much greater than the speeds of the bodies within the system, as well as the speeds of the relative motion of the reference frames. In the dynamic aspect, observation is thought to be non-destructive, so that the energy transfer between the system and the observer is always negligible compared to the energy transfer between the parts of the system.

The observer of relativity theory is much smaller, being comparable in size with the individual bodies constituting the physical system (the frame of reference), rather than with the whole system, like in the classical case. Alternatively, the speed of communication between observers is comparable with the speeds within the system.

On the contrary, the observer of quantum mechanics is extremely large, much greater than the system observed, so that the fine details of the system get lost in observation. Quantum observer can only control the system's behavior through boundary conditions, never directly interacting with any of the system's constituents.

To summarize, classical mechanics implies a quite definite model of the observer, different from the observer of relativity theory, or quantum mechanics. However, the observer's interference with the system's behavior (measured by energy transfer between the observer and the system, as compared to any "internal" energy transfer) is assumed negligible *in all the three cases*; otherwise, there could be no *physical* measurement, and no *physical* science. The consistency of the physical description of nature is ensured by treating the observer on the same footing as any other physical system; the observer enters a physical theory as a kind of *constraint* entirely describable in terms of the same theory. For instance, in physics, one does not need to consider the observer's consciousness, or economic position, which would be more appropriate to psychology or political economy. However, formal analogies are quite possible, and one could say, for instance, that K. Marx's demand to account, in a social theory, for the class roots of the historian is a close match of the paradigm change in the transition from classical to relativistic physics.

Prejudice 2: *Different physical paradigms must be compatible within a unified theory.*

This statement is commonly related to the well-known correspondence principle, demanding that new theories must include their predecessors as special cases. However, the two principles are essentially different. A physical system may admit complementary descriptions referring to uncorrelated aspects of the system's behavior; such "parallel" theories can develop in a relatively independent way. For instance, a thermodynamic picture is qualitatively different from the kinetic description, and one can never be reduced to another without conceptual strains and hidden logical circularity. The correspondence principle is only valid for the theories of the same kind, and it may be broken in an entirely new theory suggesting a complementary description of the same physical area.

One could consider such independent paradigms as separate theories, despite the fact that they apparently apply to the same observable things. That is, the definition of the object will include, in addition to the specification of the material scope, a reference to the range of the physical phenomena selected by this particular approach; a physical system viewed from a different angle is a different physical system. In this view, any mixed model (combining different paradigms) can develop into a boundary science well distinct from the original theories, and possibly treated as more fundamental.

The hierarchy of paradigms in science reflects the diversity of our everyday activities and the objectively different types of their organization. However, the general line of cultural development is directed towards a wider unification of activities; operations that formerly required professional differentiation can be naturally combined in a uniform activity of the same person. For instance, the universal computerization has introduced yet another intermediate level between the idea and its implementation; the principles of control are the same for all kinds of software, and an average user can do, in a mouse click, what earlier required several specialists of an advanced qualification. Of course, this is the level of simple standardized solutions; still, with a wider availability of universal tools, the boundary between unqualified and professional work will shift up, also influencing the organization of special training. Thus, Web pages can be easily generated by anybody using any of the numerous HTML authoring tools, or right from a regular office document; industrial Web designers will probably stick to special development platforms, with minimum knowledge about the underlying technologies; the low-level optimization will still require mastering a number of programing languages and the intricacies of their implementation. Similarly, different physical theories can be absorbed by a more general approach describing the related phenomena in a simpler and more elegant way; this does not remove the necessity of special models adapted to some particular cases, and such “derivative” models do not need to be compatible with each other. For illustration, one could observe that, say, the technical skills in ballet and ball dances are based on the same laws of the dynamics of human body; but a ballet dancer can hardly compete with a professional ball dancer, and a ball dancer cannot be expected to professionally dance ballet.

Prejudice 3: *A relativistic theory does not admit any synchronization across a space-like interval*.

In the popular literature, this statement takes an even more striking form: there can be no synchronized distant events. This vulgar formulation is obviously absurd, since two material points moving in different directions from the same point will finally be far away from each other, but the interval between them will remain time-like, since material points cannot move faster than light; the movement of such diverging points will remain synchronized if it was synchronized in the starting point (provided the synchronicity is not broken by local interactions). For instance, the two particles in the EPR experiment will always be correlated; for another example consider a spherical wave, with the phases of very distant points remaining correlated at any moment.

Synchronized events separated by a space-like interval are also possible: if such a synchronization has once occurred, it will pertain in any frame of reference, according to the principle of relativity. The very notion of a reference frame is based on this possibility, since any frame of reference implies synchronization of the clocks located at any (including space-like) intervals from each other. A plane wave is, probably, the most common example from relativistic field theory: the phases of all the points in all the space-time are correlated in the plane wave, including the points outside the light cone. This inherent nonlocality of plane waves makes them so valuable in quantum field theory, allowing a covariant description of quantum states.

Obviously, the existence of a plane wave implies an infinite source, which would not obey the laws of relativity theory. All *local* events (the only ones possible in a consistently relativistic theory) would only produce outgoing spherical waves, and never plane waves. The handbooks on physics often treat a plane wave as a small part of a spherical wave far from the source. This approximation is only possible in the non-relativistic limit, and hence it cannot justify the usage of plane (or incoming spherical) waves in relativistic field theories. The inconsistency of introducing nonlocal objects in a local theory manifests itself in a number of conceptual and formal difficulties; renormalizable singularities are among the most common. However, while the nonlocal objects thus introduced do not enter any interactions, they can exist in theory without raising any contradictions, in a covariant way.

Prejudice 4: *Independent measurements are possible in quantum mechanics*.

This is a logical contradiction, since a quantum observer occupies all the space, so that any two measurements will necessarily be correlated. However, the energy transfer from the observer to the system can be minimized if the observer does not directly interact with the system to study, but rather with some other microscopic systems serving as “probes”. Quantum experiments typically employ the scattering setup, with the observer controlling the state of the projectile (the probing particle) and any outgoing (scattered) particles only at “infinity”, far from the target (the quantum system of interest). The interaction of a probing particle with the target can be made weak, that is, comparable with interactions within the target or weaker. The interaction of the observer with the scattered projectile at “infinity” is believed to little influence the state of the quantum system just because it is “too far”; this is a very strong assumption that fails to hold, for instance, when macroscopic events are globally synchronized and one cannot disentangle the observer from the system even asymptotically. Still, the model of an “asymptotic” observer remains one of the fundamental parts of the formalism of quantum mechanics.

Considering the relations between quantum theory and relativity, one could note that the two outgoing particles in the EPR experiment will be always correlated if detected *by the same observer*; this implies that measurement can only be “adiabatic”, that is, the time of measurement must be much greater than the characteristic times of relaxation processes within the system. For an analogy, recall the well-known result about the absence of absolutely rigid bodies in special relativity theory. As the time of measurement becomes comparable or smaller than the internal ticks of the system, energy transfers thus implied will prevent any distant measurements performed by the same observer; if two observers perform measurements in different spatial points their communication will take an additional time, which has to be accounted for in analyzing experimental data, with the necessarily introduced significant corrections.

Prejudice 5: *EPR-type experiments could be a test of the validity of quantum mechanics against local theories, including relativity theory*.

The falsity of this statement follows from the above. Any possible experiment is either local (compatible with classical dynamics), or it will be an essentially nonlocal quantum experiment. In the first case, any measurements on one outgoing particle do not depend on the measurements on the other, and hence putting them in sync would require a special process significantly modifying the scheme of measurement. On the other hand, to stage a quantum experiment, we need to keep within adiabatic limits, so that the particles would effectively always remain *in the same point*, with the zero interval between them. In the quantum scheme, there are no separate particles that could be distinguished in observation and probed independently; rather, there is a quantum system consisting of the incident two particles plus, possibly, some other objects, representing the interference of the observer.

If local measurements happen to be correlated, this only means that the system has been *prepared* that way, and global correlations have been introduced in a nonlocal process, after which they can pertain in all the frames of reference. Quantum physics is entirely based on the concept of “system preparation”, implying a kind of the observer’s involvement in the system’s motion. Formally, this means eliminating a number of dynamic variables through imposing various *constraints* (including pre-supposed symmetries and the corresponding conservation laws). Thus, in the EPR experiment, we do not deal with two independent particles, with three coordinates and three momenta needed to describe the state of each particle; we can effectively eliminate three coordinates and three momenta (or any other six variables) and effectively deal with a single particle. Consequently, there is no particle synchronization violating relativistic locality, and no problem at all. All we observe is the phases of the same wave; no wonder that they are perfectly correlated. To introduce relativism in an essential manner, one has to consider two independent (separated by a space-like interval) observers; such observers cannot communicate their results to each other, and hence there is no restriction on the "simultaneous" measurement of coordinates and momenta, as imposed by the uncertainty principle.

Prejudice 6: *Bell's theorem allows experimental falsification of the hidden variables approach in favor of quantum mechanical treatment*.

Bell's theorem and its reformulations (like CHSH), like any other formal results in science, are based on very special models, so that all the implications would apply to these original models, without touching any universal principles. Hidden variables (or other classical models for quantum experiments) can be introduced in many ways, and no theorem can cover all the possibilities. If the results of some experimenting happen to violate Bell's (or CHSH) inequality, this can only put in question the premises of a particular derivation, and possibly, the adequacy of interpretation. If some other results lie within the formal limits, this can neither prove the validity of the model, nor indicate any incompleteness of quantum mechanics; all we can is to suspect some inconsistency in the experimental setup violating the "pure" quantum-mechanical scheme. From the philosophical standpoint, the hierarchy of the world will certainly reveal an infinity of cases intermediate between classical and quantum physics and additional levels can be found "below" quantum physics and "above" the classical scheme.

Bell-like inequalities are a special case of *applicability conditions* that are required from any sufficiently developed physical theory, regardless of its generality. Such inequalities can be formulated for any model at all, from the configuration interaction approximation in the physics of autoinization to general relativity and cosmology. It is important that applicability conditions be derived *within* the theory. If the derivation is to compare *different* theories, this is a logical fallacy; provided the deductive scheme is correct, we conclude that the derivation is applicable to neither of the original theories, but rather refers to *another* theory describing a boundary situation.

Prejudice 7: *Quantum mechanics needs interpretation*.

Quantum mechanics has always been a matter of philosophical speculation, and many people tried to "translate" it into the ordinary language, or a metaphysical slang, explaining its peculiarities by anything else. The Copenhagen interpretation is one of the most famous projects, representing the "mystical" camp; it claims that consciousness is to play a decisive role in quantum measurement, producing a kind of "state reduction" or "quantum collapse". Since the adherents of that school do not really know what they mean under consciousness, there is always enough room for idealistic speculation and pessimism about the people's ability to comprehend anything at all.

A productive group of interpretations suggests various semi-physical models to explain the probabilistic nature of quantum mechanics, nonlocal correlations, complementarity or uncertainty principles. One could mention hidden variables theories, semi-classical interpretations, many-world interpretations, or advanced-action and transactional models. However, interpretations of that kind are irrelevant to the regular problems of quantum physics, or relativity theory, and no practical solution really needs them. Still, such interpretations could be useful as a specific form of creativity in theoretical physics, stimulating the search for new paradigms explicating new aspects of reality, different from both quantum world and relativity.

As a physical model, neither quantum mechanics not relativity theory needs any interpretation. On the contrary, such general theories serve as a framework for interpreting physical experiments and observations, regulating construction of special physical theories aimed to explaining particular classes of phenomena. It would be a *logical* error to speak about the "incompleteness" of quantum or other theory. They are not intended to be complete, since the very nature of science is analysis, characterizing the system of interest from different aspects, complementary (and hence irreducible) to each other. There are as many such aspects as one likes, and there is always room for yet another paradigm.

Prejudice 8: *Physics can explain phenomena related to life or consciousness*.

No, life can never be reduced to mere physical or chemical processes, and consciousness cannot be explained by mere physics or biology. It would be naïve to expect an insight into the nature of the human mind from a study of particles and fields within the brain. A physical experiment is to bring physical data, entirely interpretable within the physical science; otherwise, it would not be physics. And within physics, the possible influence of the observer can only be accounted for on the physical level, in physical terms. To study life and consciousness, one needs experimenting of an appropriate character, directed by the conceptualizations of the same level. Any usage of physical terminology in, say, psychology can only be metaphorical.

This does not mean that the formal models originally developed in physics are never applicable in other sciences. In particular, one can describe psychological phenomena using the formalism of classical mechanics, quantum mechanics or relativity theory, provided all the quantities thus introduced are reinterpreted in the psychological terms, referring to psychological processes rather than physical motion. For instance, one cannot speak about a mass of a thought; but one can consider psychological inertia as a specifically psychological phenomenon. Similarly, psychological dynamics will be described as an interplay of human motives, rather than the balance of physical forces. A similarity of the form does not imply the same content.

The applicability of the same formal scheme in many different sciences is primarily due to the commonality of the culturally established modes of activity, which may be difficult to perceive. Thus, a weight on a rope, electric current and a planet moving around a star may seem entirely different and having nothing in common; still, they all could be approximately modeled with the same notion of harmonic oscillation. With all that, the physics of a planet's motion around the central star is quite unlike the dynamics of an electron in a wire. Physically different processes may have identical formal *schemes*; this is a consequence of their involvement in the integrity of human activity.

Time *vs*. Interval

The modern approach to special relativity is to merely postulate the symmetry group $O(1,3)$ in the four-dimensional space-time, which assumes the invariance of the interval defines as

$$ds^2 = c^2 dt^2 - dx^2$$

or, in the covariant notation,

$$ds^2 = g_{\mu\nu} x^\mu x^\nu ,$$

with $x^0 = ct$ and the standard signature for the metric tensor: $g_{\mu\mu} = (1,-1,-1,-1)$, $g_{\mu\nu} = 0$ for $\mu \neq \nu$.

However efficient, this formal introduction can hardly satisfy anybody interested in the physics of space-time. Why should we choose a construction like this? Well, this choice agrees with the bulk of experimental data, and it works fine in the applications. Still, the nature of such unity of space and time still lacks clarity and we cannot indicate the physical conditions necessary for these equations to be valid, that is, the range of applicability for the special relativity theory. In physics, this should be considered as a serious drawback, an evidence of incompleteness, since no scientific theory can be universally applicable, and any closed theoretical system must clearly outline its scope.

The early explanations used to derive the invariance of the interval from a number of physical principles, such as the equivalence of all the space points and moments of time (hence translation invariance), the independence of the system's behavior of orientation (hence spatial rotation symmetry), and finally, the constancy of the speed of light in all the frames of reference (which leads to the symmetry in respect to hyperbolic rotations). Although one could contest the validity of argumentation, the very attempt to bind the foundations of theory to the common forms of human activity provides a basis for further investigation and the possible generalizations. Special relativity thus becomes a matter of experimental tests, rather than an abstract idea supported in an indirect manner by the validity of its implications, which is a very weak form of justification, since experimental setup is derived from the theory to prove, and therefore the results are expected to be compliant with it in advance.

There is yet another relativistic principle that does not follow from mere geometric symmetries, requiring certain assumptions about the character of dynamics. The famous Einstein's formula establishes equivalence of mass and energy: $E = mc^2$, with dynamic mass introduced as

$$m^2c^2 = m_0^2c^2 + p^2.$$

The nature of the rest mass m_0 is beyond theoretical discussion; however, everybody agrees that it should be dependent on the material of the particle and its inner motion. The rest masses of the so-called elementary particles are generally considered as physical constants, though some modern theories pretend to derive these masses from other, presumably more fundamental parameters.

The relativistic dynamics of a material point can be derived from the principle of minimal action if the action of a point particle is related to the interval by the equation

$$dS = -m_0cds = -\sqrt{m_0^2c^4dt^2 - m_0^2c^2dx^2} = \sqrt{E_0^2dt^2 - p_0^2dx^2},$$

where E_0 designates the rest energy of the particle, while p_0 stays for a kind of momentum associated with the rest mass. Alternatively, one could consider the interval as scaled action; the role of variation principles in physics is yet unclear, though all the fundamental theories are traditionally required to comply with that formalism.

The idea of a kind of parity between space and time seems rather natural, since distances are practically measured by the time required to cover them in a standard pace. In particular, this could be the number of times necessary to apply a ruler to a segment of a line, or the time required for a light wave to propagate from one end to another. In relativistic physics, the logic is exactly the inverse: we measure time by the distance covered by light. This fundamental assumption seems to introduce a hidden logical circularity, and the independence of the speed of light of the reference frame may be an artefact due to the usage of light propagation as the measure of time. However, this circumstance does not play any important role as long as we have no other choice; postulating the constancy of the speed of light in the relativity theory, we simply forbid the very existence of such an independent measure.

Just to illustrate the possibility of an alternative treatment, let us rewrite the definition of the interval as follows:

$$dt^2c^2 = ds^2 + dx^2.$$

Comparing it with the definition of dynamic mass,

$$m^2c^2 = m_0^2c^2 + p^2,$$

we observe a suspicious similarity, which probably is a mere coincidence, but which also may suggest a different interpretation of special relativity. Instead of reducing time to space, we could say that time results from the hierarchy of the particle’s motion, including both spatial displacement and inner motion producing the rest mass. In this picture, the description of motion in the configuration space is dual to its representation in the momentum space, which is quite natural since the two space can be considered as mere Fourier transforms of each other. That is, moving along a virtual trajectory of the particle, we observe (or apply) a certain action, which, together with the length of displacement, determines a natural measure of time, and the variations of trajectories are to minimize this value. In particular, this implies the existence of the *arrow of time*: even for a particle at rest, time will always accumulate due to inner motion, and any explicit displacement will make it run faster. This is much closer to our intuitive notion of time, and the production of space-time by developing matter appears to be more straightforward and consistent. The invariance of the interval is then naturally explained by its correspondence to the rest mass as a constant of motion.

Although this approach may seem to violate translation invariance in time, this is not so, as long as the transition from one moment of time to another (the system’s development) does not change the character of its dynamics (compare it with self-similarity in fractals). On the other hand, for some types of development (namely, those involving an inner reorganization or collective behavior), translation invariance in time will certainly get broken, and this perfectly agrees with our idea of irreversible dynamics.

In the hierarchy of motion, the cluster of spatial trajectories of one level becomes a part of the inner dynamics of another, and conversely, inner dynamics can always be unfolded in a kind of translation plus inner dynamics of a deeper level. In general, the levels of this hierarchy will have different natural measures of time associated with different reference processes. For instance, the inner time of a quantum system may result from an entirely new kind of interaction propagating much faster than light. This ensures an essentially collective behavior of quantum systems for a macroscopic observer, who will formally treat the virtual events as occurring “in no time”; hence the indistinguishability of particles and exchange effects.

The configuration space of inner motion is hidden from the observer; that is, it develops within a spatial point of the upper level. It looks like a particle can leave its “macroscopic” trajectory and get back without noticeable delay. In other words, inner motion can be modeled on the macroscopic level as virtual oscillations, so that their frequency would determine a part of the rest mass, along with a hierarchy of lower-level oscillations. In the plausible assumption that each level of hierarchy allows just a few modes of oscillation (standing waves), we come to a spectrum of masses, which will obviously depend on the level of consideration.

Now, the standard relativistic theory gets included in a general context, and the limits of its applicability can be discussed on a universal basis. We conclude that the constancy of the speed of light is equivalent to the assumption of the lowest (the most fundamental) level of matter; the versions of this assumption were put forth many times in the history of science, but they proved to be just temporary limits every time. Quite probably, a generalization of the theoretical scheme will get rid of many relativistic singularities, which are all due to the singular character of Lorentz group. The zero rest mass of photon means that we do not consider any inner motion; as soon as photons are allowed to undergo a series of virtual transformation, they will acquire non-zero self-energy; such “structured” photons will propagate slower. Physical vacuum is not an empty space, and therefore assuming any special role for the light speed in vacuum is nothing but a useful abstraction. Nothing prevents us from admitting a more complex organization of matter (including vacuum) and discovering new kinds of inner motion within photons. Who knows? Maybe a special role of gravity is to link one level of this hierarchy to another.

Black Holy Logic

Today, it is unanimously accepted that the Universe swarms with the so-called black holes. Astronomers report hundreds of already identified cases, while the observable behavior of many other radiation sources can only be explained by the presence of a yet undetected massive companion, presumably a black hole. The presence of black holes in galactic nuclei and quasars is considered a well-established fact beyond any discussion. For all that, the nature of black holes remains as dark as in 1915, when Karl Schwarzschild has found his second (“outer”) solution of Einstein’s equations, or as in 1964, when the term “black hole” was coined. So far, the only meaningful definition of a black hole can only state that it is a compact massive object that cannot be described by any existing scientific theory in a consistent manner, eliminating any unphysical singularities. Picturing black holes as monsters devouring matter is more appropriate in yellow press than in a scientific or philosophical discussion.

I am not going to delve into mathematical intricacies and the details of formal derivation. These can be found in the special literature. My goal is to draw attention back to the practical foundations of science and its logical structure; any topic will do for that purpose, black holes being no worse than anything.

The mathematical abstraction of infinity is practically useful, since it allows us to split complex problems into more tractable parts without too much computational overhead. The word “infinite” could be translated into common language as “providing enough room for action without bothering about applicability issues”. In real nature, there no zeroes and infinities, as well exact equality and identity. At any moment, we choose a limited number of nearest goals, with all the rest serving as a rich background. As long as we can make yet another step forward, we have an infinity in front of us. Sometimes, this freedom would take on the sense of “too much”, as we get tired of keeping on with the same activity and seek for a different occupation. This sort of behavior has been reflected in the dialectical principle of measure, indicating that quantitative changes cannot accumulate but within some natural limit; when some quantity becomes excessive, a qualitative leap will necessarily follow. Any physicist learns this attitude in school; but then some theoretically minded individuals happen to forget it and switch to a religious belief in the physical existence of mathematical abstractions.

So, let us repeat once again: there are no infinities in physics. Speaking about point particles, or material points, we only mean that some physical systems can be treated *as if* there were a point source somewhere far away. Speaking about singular potentials, we mean that they are *like that* far enough from the point of singularity. Speaking about infinitely remote regions in space and time, we only *discard* any influence of distant objects to the dynamics of interest. In this respect, physics is like computer science, where continuous models can be used to derive meaningful statements about essentially discrete systems. In physics, we are always to guard the limits of measure; if something grows or diminishes too fast, it's high time to change the scale.

The mystical feeling towards the power of mathematics makes people forget that mathematics too is not free from inherent logical problems, and even the most rigorous inferences are based on a shaky foundation of very strong assumptions, restricting our reasoning so that we would inevitably arrive to the desired conclusions. In the strict sense, mathematics is mere tautology, it is entirely based on logical circularity, and mathematical truths are of no use unless we break their ostentatious rigor and apply formal results to something obviously informal.

Black holes provide a vivid example of a logical hole in theoretical physics. Normally, any mathematical result will only be used within the limits of its applicability. Extrapolating any formulas beyond this area is acceptable as a loose analogy, or even a metaphor, but never a means of scientific study. Such a deliberate departure from the logic of science can be a kind of probe to mark out the boundaries of the applicability region and indicate the promising directions of development. With black holes, the sense of measure has abandoned the minds. An evident contradiction becomes an occasion for loose speculations far from any scientific standards.

Indeed, trying to obtain an exact static solution of the general relativistic equations, Schwarzschild originally assumes that there is a point mass, and its gravity is to determine the structure of the whole space. After a number of formal manipulations, he comes to a formula strictly isolating one region of space (the Schwarzschild sphere) from the rest, so that the point mass staying inside the isolated region can no longer be responsible for any physical effects at longer distances. This is an obvious contradiction, but it does not prevent us from using this theory in the space areas far from the center of gravity, with the reservation that the validity of results in the regions closer to the mass is to be verified using a more accurate approach. This kind of trade-off between mathematical rigor and physical sense is quite common in physics. For instance, the well-known Rayleigh–Jeans law describes the spectrum of blackbody radiation at low frequencies, but fails to converge for shorter wavelengths, which was known in the early 1900s as the ultraviolet catastrophe. On the contrary, the Wien's approximation works fine at high energies, but fails in the long wave domain. To reconcile the two limit cases, Max Planck has suggested a semi-empirical distribution that has been found to correspond to the picture of quantized radiation. This how the triumph of quantum physics began. The theory of black holes might reproduce that story. The inner and outer Schwarzschild solutions could be interpreted as the limit cases of a general law introducing a new physical constant (virtually equivalent to some fundamental length) and opening a new chapter in the history of physics, marked with a natural synthesis of quantum physics and relativism.

The adepts of black holy logic will certainly object. They believe that the Schwarzschild solution holds both for the outer and inner regions of the critical sphere, and the presence of singularity reflects the complex nature of gravity. Those who disagree are obviously lacking phantasy and education to acknowledge the great discovery of the XX century.

Just for comparison: there is yet another relativistic singularity, which the same believers are inclined to treat in an entirely different manner. Trying to derive the Lorentz transform from a few basic physical assumptions, we come to a singular solution dividing the whole space-time into two disjoint regions, just like the Schwarzschild solution does with gravity. However, in this case, everybody agrees that any communication between the objects separated by a space-like interval is utterly impossible, and they cannot influence each other's dynamics. Following this logic, we should admit that a point mass inside the Schwarzschild sphere were entirely hidden from the outer observer and, of course, it could not produce any physical forces.

For an unprejudiced thinker, the presence of any formal singularities in a physical theory means that its basic assumptions are not universally valid, and we need to reconsider the foundations of the theory in the regions of extraordinary behavior. This is a general principle working in classical physics as well as in relativistic and quantum theory. Thus, in classical electrodynamics, we can consider electrically charged point particles, which immediately results in a singular potential in the region around the source. This approximation seems to be experimentally proven up to very short distances, but we can predict, on the logical grounds, that there must anyway be a limit where we'll need to question the validity of the traditional notion of electric charge and reconsider the very idea of a point particle. Moving down to the center of an electron, one will eventually come to a different picture of reality, an inner space of the electron with the electron's charge being s global property of this inner structure, which may be quite different from mere spatial distribution.[1] In a way, the Schwarzschild singularity is related to the same abstraction of a point particle, though we do not yet any experimental evidence of an essentially quantized spectrum of mass. Approaching the Schwarzschild radius, we'll get in a new space related to the usual mechanical space in a statistical manner.

It is well known that quantum physics does not remove any classical singularities, as it is entirely based on the same spatiotemporal continuum. In other words, we still stick to the abstraction of a point particle, albeit represented by a continuum of its virtual clones. The configuration space of quantum mechanics (and, of course, quantum field theory) consists of all the possible distributions in a virtual space-time, which only aggravates the malady, admitting functional spaces much more powerful than mere continuum. Modern string theories suggest a logically attractive remedy against any unphysical singularities: all we need is to add yet another spatial dimension and get over the singularity through that additional dimension. That is, a singularity appears when a regular structure gets projected onto a subspace of the whole space, as an artefact of a narrowed view. However, one could readily predict that string theories will necessarily face the same difficulties, as they fight one kind of singularity introducing yet another kind, in higher dimensions. Instead of sweeping the junk under the carpet, we rather stock in on the roof.

In the heart of the problem, we find the old philosophical question about the nature and role of discreteness and continuity in the physical world and human activity. One cannot dismiss neither of these poles; they are irreducible to each other and hence need to be treated as complementary aspects of any reality to be reflected in a consistent reasoning. As far as I can see, the only possibility of reconciliation leads to a hierarchical approach combining the opposites on a developmental basis, so that the points and infinities of one level would become extended structures on another. The formation of such a hierarchy is a natural process like any physical motion, but we can only reflect it in our notions and actions to the extent of our cultural development, that is, within the already assimilated portion of the world.

Meanwhile, let us discuss yet another logical fallacy in the theory of black holes. Modern cosmology says that black holes normally appear in the gravitational collapse of the stars that have burned off their stock of hydrogen and helium so that the weight of the outer layers of the star can no longer be countervailed by the pressure of radiation produced in thermonuclear reactions. For the stars with the mass greater than some critical value (above 3-4 solar masses), this collapse will push the star's matter into the Schwarzschild sphere, and then the newborn black hole will grow absorbing matter and radiation from the nearby space. The special literature is replete with the calculations of such accretion; the overall picture is unanimously accepted by all the specialists, and any physical models only differ in minor details to be adjusted in the future complete quantitative theory.

[1] For the observer, such a distribution would sum up to a kind of electromagnetic form-factor, which is not the case, at least at the present level of experimental techniques.

Here an arrogant dabbler butts in once again with his idiotic questions. Do stars really need to collapse? Well, in some cases they could behave that way, for instance, producing neutron stars that have nothing singular about them and hence are quite acceptable from the logical standpoint. But why should we admit the real existence of unphysical infinities for collapsing stars above the Chandrasekhar limit? Isn't it more natural to fancy a peculiar state of matter that would stand the gravity of the outer layers without any supernatural assumptions about adjacent worlds and wormholes?

For an illustration, let us look at our buildings, the solid constructions that do not collapse under their weight despite the fact that the atmospheric air inside then can hardly resist the pressure of stone, steel and glass. Moreover, within our houses, we do not feel the weight of all the stories above us, though, of course, we would be smashed flat if the construction lost its balance for some reasons. This is possible because different states of matter are differently organized, and, in particular, solids are very unlike liquids and gases. The distribution of pressure in solids is essentially anisotropic, and that is why an empty solid sphere would not collapse to its center, even if we put there yet another mass. The Newtonian theory of gravity tells us that the gravitational potential within a thin massive sphere is exactly zero everywhere in the whole volume. That is why we should not expect any excessive pressure inside a solid ball of any mass at all. Moreover, the gravitational potential and pressure in the center of such a ball could be close to zero.

All the theories of star evolution picture them as gas balls obeying the standard laws of gas dynamics, slightly modified to account for relativistic and quantum effects. A star is assume to be in the same phase state all over its volume during all its life. Thus, the classical Landau's paper (*To the Theory of Stars*, 1932) described the collapse of the cold Fermi gas; obviously, in the process of collapse, the gas cannot remain always cold (there is no such thing as adiabatic collapse), and its temperature (along with the Fermi energy) will rapidly increase with compression beyond a certain physical limit. The logic of collapse is inapplicable to very hot systems, and therefore, probably, to the absolute majority of astrophysical objects. So, what is the use of that much ado about nothing?

As everybody learns from everyday experience, even the same phase state of matter feels quite differently in different conditions. For example, the air is normally thin and impalpable, but it becomes very dense and viscous in the strong wind, and it can even kill, in the form of a shock wave. It seems natural to admit that, in the conditions of extremely high pressure, matter could develop much more efficient modes of resistance preventing any collapse. Such an assumption would be much more reasonable than the mystical realization of abstract singularities. For one possibility, very hot compressed matter could transform into pure radiation, or into any other state without any massive particles, well before reaching the Schwarzschild radius. A kind of photon gas could then be compressed to a photon liquid, or even into a solid; this is contrary to the traditional electrodynamic picture of non-confinable photons; however, the latest achievements of quantum technologies indicate that a system of photons can indeed form something like bound states. Eventually, a part of gravity force can become radiation, or conversely, radiation could become a sort of repulsion gravity preventing too much gravitational compression. Of course, these are merely fantastic hypotheses, but they demonstrate how futile the discussion of gravitational collapse, black holes and similar matters can be in the face of the real complexity of the material world. One should not trust too much all what physicists use to say. Anyway, they are certain to change their opinion if nature is insistent enough.

With more options that might come form the possible singularity-free generalizations of general relativity, the chances for the formation of black holes in gravitational collapse become practically infinitesimal. However, there is still some room for black holy logic as it comes to considering such extremely massive objects as galactic nuclei. Today, we have collected presumably convincing astronomical evidence of very compact massive bodies in the central regions of some spiral galaxies. Extremely massive compact bodies are also deemed to be responsible for the activity of quasars. Well, let us admit for a while that we need black holes to explain such observations. This will raise the same question: how that huge masses could accumulate? The traditional accretion picture obviously does not work in this case. Even if galactic nuclei were believed to exist long enough to pack so much matter in a black hole, this is certainly not the case for quasars that are deemed to be among the oldest astronomical objects, and therefore, their hypothetical black holes, in the cosmology of the Big Bang, just would not have time enough to grow to the scale observed.

Of course, there is always the magic wand of cosmic catastrophes. In the young (and more compact) Universe, the chances of galaxy collision should have been much higher, and that is how the old quasars could form. Unfortunately, in this case, we have to abandon the very convenient hypothesis of a genetic kinship between active galaxies and quasars, but one can surely afford that, to save a sheer mathematical abstraction!

But there is yet another aspect of the problem. As commonly known, the Schwarzschild radius is proportional to the mass M. Now, the average density of matter inside a sphere of radius r is defined as M / r^3; this means that the densities required for the formation of a black hole are $\sim 1 / M^2$. That is, for the masses of the metagalactic scale, black holes could easily form from a very cold and rare gas, without any need for collapse, or other dramatic events. In the generally accepted framework of cosmological expansion, black holes could form in piles before any galaxies and stars were born. In this picture, our Universe would certainly swarm with black holes, which were to *precede* stellar evolution rather than be its final stage.

All right, let us assume for a moment that this was the true mechanism of the formation of galaxies. First, many black holes of all sizes formed in the early Universe, they grew in pace with the cosmological expansion and became the centers of attraction for the surrounding gas to form stars and galaxies. This is exactly the inverse of the traditional picture, but who knows? This picture can perfectly explain the mysterious dark matter as a gas of microscopic black holes a hundred times heavier than proton. What a space for theoretical imagination!

However, if we make yet another step towards the origin of everything, we stumble over the obvious conclusion that, in a very tender age, the *whole* Universe should stay *within* a black hole! The Schwarzschild radius for the total mass of the Universe is huge, and we do not need to go too deep in the heart of the proto-matter to get drowned in the progenitor black hole. The usual laws of physics are enough to explain the material dynamics of that time. So, how could we get out of the mess?

One possible answer is that there is a hierarchy of black holes, and we still live inside a higher-level black hole, while new black holes are born as a result of gravitational collapse. In this case, we must admit that the inside of any black hole is just a Universe like ours; and our Universe too has resulted from some instance of higher-level collapse. Such a picturesque view could gain easy popularity and generously stimulate the writers of science fiction.

On the contrary, a physicist would rather prefer a less exotic, and probably too dull an explanation. The obvious objection is to indicate that in the homogeneous proto-Universe we cannot use the second Schwarzschild solution that was designed for the *empty* space around the gravitating mass. By why then do you apply the same solution to collapsing stars? Do you think they contain sheer vacuum? Why do you interpret the experimental evidence in terms of a mathematical abstraction that is entirely due to the insufficiency of the present physical theory? All we need is to get rid of the unphysical singularities, and the way we do it will immediately tell us how our views on the early history and the destiny of the Universe should be modified.

No doubt, having done with black holes (and all the logic behind them), we'll have next to give up the cosmological singularity, on the similar grounds. The idea of expansion from nothing is yet another illegal extrapolation; it has nothing to do with physical reality, being a mere approximation that can only be used in the regions far from singularity. Quite probably, all such relativistic singularities are due the very basics of relativity theory, to the singular character of the Lorentz transform. The future generalizations are to remove this primary singularity, thus enormously extending our view of the Universe no longer limited by the light barrier. In this greater Universe, local expansion will always be complemented by as local contraction, and the very presence of such cosmological effects will be explained by the specific choice of the reference processes and the corresponding structure of the frames of reference.

When science grows to more maturity, it will certainly drop the childish habit of stretching a special physical theory onto the whole Universe. The world is bigger than any human fantasy; it will always be a source of surprise and discoveries for any science at all, including physics. Conscious beings are eventually to get conscious of that circumstance as well.

Observers, Time, and Velocity Measurements

Today, everybody knows that the speed of light does not depend on the motion of the source and that it is the same in any frame of reference. This fact has been confirmed by very accurate measurements; it is also supported by the overall consistency and impressive progress of modern physics entirely based on this assumption. As a consequence of this picture, we cannot move faster than light, and our ideas about space and time have to reflect their interdependence albeit leading to uncomfortable differences in the picture of reality for different observers. Of course, the classical picture of entirely separated space and time, the same for all observers, was simple and attractive. Nevertheless, science has to follow the turns of reality, however crazy they would seem to a primitive mind.

Still, one is always free to ask why. Thus, in the ancient times, people simply accepted the regular motion of the sun and the stars across the sky as a physical fact; this lead them to adjusting their measures of time to the observed regularity. The characteristic periods of this motion should be considered as fundamental constants, and this view was equally practical in both Ptolemaic and Copernican pictures of the world. Later, Sir Isaac Newton has explained us that all such regularities could be derived from a simple law of attraction that was named universal gravitation—just to denote something we do not yet understand. Some newer theories admit that the gravitational constant from Newton’s law could be derived from a more general theory, along with a number of other fundamental values. There is no reason to take the speed of light for something special, and we could lump it to the same pile.

Historically, the relations between physics and reality provoked a lot of debate. It is quite obvious, that all our notions refer to the aspects of the world that have already been included in our practical activity, and we do not care for theories of something beyond any (at least speculative) accessibility. It is important that human activities are never confined to mere cognition; moreover, cognition is rather an auxiliary activity serving to our principal goal of rearranging the world to better satisfy our needs. Still, the essentially practical nature of cognition leads many thinkers to belief that there is nothing at all in the world beyond human activities, and that the whole nature must be treated as an artefact, the result of our active attitude to the world. In a way, they are right, as long as the present state of human development is concerned, regardless of its origin and the prospects of the future. However, when we consider developing activities, we need to think about the source of this development, unless we are apt to take the world for mere play of imagination. It would be quite natural to admit that the world is much wider than our present experience, and that is why we are always bound to get new, unexpected experiences in the future. This “world on itself” is not static, and therefore our experiences will grow not only through expansion assimilating the new parts and aspects of the Universe, but also in an intensive way, due to the development of the world itself. That is, we can never have a “complete” picture of the world; there will always be something to add, or something to change. Some would find it disappointing; some others would greet it as a source of infinite fun.

In particular, our ideas of space and time are necessarily dependent on the range of activities available at the moment. The earlier notions of space and time were different, developing from the patchwork of disjoint local environments to the classical mechanistic vision of space and time as static universals. When we bind these universal space and time together through the introduction of a universal constant, the speed of light, we reproduce, on a higher level, the primeval ideas of space measured by time, and time determined by the spatial positions of the visible objects. The obvious corollary is that a wider vision of this interdependence as a special case of a more universal picture will require at least one alternative “space-time” constructed on a different basis. In the developing world, the constancy of the speed of light could be a local phenomenon due either to the limited experience of our observations, or to the present state of the world’s evolution. That is, even with the present technologies, one could expect detecting certain variations with time, or somewhere far away. Alternatively, one could admit that our relativistic space-time is an artefact of the present measurement schemes, and that new independent measurements would reveal considerable differences. As usual, any combination of the two possibilities is also possible.

As we cannot say anything meaningful about the unexpected, let us look closer at what we have at hand. The very idea of motion is nontrivial, since one has to consider two successive states of the system at once, relating them to each other as "previous" and "subsequent". But how can one compare two entities, of which one is already gone, while the other has not yet come? This assumes that there an entity comprising both the initial and final states, something that does not change with them and hence can serve as their common measure. That is, an entirely local observer existing here and now can never detect any motion, only registering the current state at the present moment. Indeed, even registering the current state becomes highly problematic, as there is no way to distinguish it from (and even to compare it to) any other state.

This argument seems to undermine the fundamental assumption lying in the basis of relativity theory, the locality of observations (interactions). It is usually said that any observer can only compare events occurring in the same spatial point. On the other hand, we admit that space and time are intertwined and inseparable; this implies that the notion of "the same spatial point" contradicts the overall covariance requiring a preferable frame of reference. Obviously, postulating a covariant locality embracing both space and time will eliminate any motion at all. This is one of the reasons for a purely geometrical vision of the world becoming so popular among theoreticians. The world, where nothing happens, where everything is already given and never subject to change… But the very idea of such a static world is an expression of extreme nonlocality expanding the observer to the whole space-time. Or, alternatively, the whole space-time is to be located *within* a single point-instant, that is, it must be the *inner* state of the absolutely local observer irrelevant to any outer motion.

To allow of any meaningful science, we have to adopt a *hierarchical* vision of locality, so that local outer motion (local interactions) are to be complemented with essentially nonlocal inner motion serving to distinguish outer events by associating them with the different inner states. That is, a local observer maps all the instances of interaction with the outer world into an inner space (taken at once, but possibly including a static counterpart of the temporal dimension). A structure thus obtained *represents* the outer world in this particular *frame of reference*.

Of course, nothing prevents us from considering more levels of hierarchy; moreover, this hierarchical structure does not need to be the same for the different aspects of the same physical system. The observer (and the frame of reference) will become hierarchical as well, being both local and nonlocal, in respect to different levels of hierarchy. In this general approach, locality is relative as anything else.

The natural organization of the outer events will induce hierarchical structures in the inner representation space. Obviously, these structures also depend on the way of mapping, which is virtually related to the currently available modes of activity. This is why the inner structures may be inadequate for the description of certain physical areas, reproducing them inside the observer in a cumbrous or ambiguous manner. However, our practical activity tends to bring our representations to a closer correspondence with the real world; in a self-reflective form, this is what we call cognition. Of course, in physics, we do not consider any conscious beings, and a physical observer is merely an equivalent name for a frame of reference associated with an individual physical object (real or virtual), provided it exists as a relatively stable formation distinguishable from the rest of the world. That is, we can speak about "observer objects" reflecting all the other objects; obviously, any other object can be chosen for an "observer", which will modify the observed picture in a regular manner determined by the physical nature of the observer objects (the level of "observation"). This generalized relativity holds for any physical systems at all, not necessarily of the same kind. The same physical world becomes reflected in a variety of relative physical pictures comparable with each other. For instance, the kinetic derivation of thermodynamic regularities could be considered as a shift of reference level within the same hierarchy. The notion of an inertial frame can be extended as well, referring to the frames of reference within *the same level of hierarchy*. In this case, the different observers will build essentially the same picture of the physical world, while any inter-level transitions require a different dynamics (like adding or elimination of interactions and symmetries).

Any outer motion imposes a definite type of structure on the inner space; namely, it produces *trajectories* (or tracks) representing the sequences of events. In general, a trajectory does not need to be smooth, without loops and self-intersections; moreover, it may be chaotic and fuzzy, so that a physical process would be represented by a bundle of trajectories rather than by a single track. Still, at any instance, there is a distinction of the present and the past: a part of the trajectory is said to occur before the current state, while the rest will represent the subsequent motion. This relation may also be nontrivial, reflecting the hierarchical organization of the "present moment". Anyway, a trajectory is a kind of hierarchical structure, with the present state lying "above" all the preceding states and "below" all the following (if the structure is to represent development, or evolution), or conversely, "below" all the past (when considered as unfolding the structure from some original state). This relativity of the past and the future is reflected in the common idea of the isotropy of the physical time.

Yet another aspect of time is related to the idea of homogeneity. Thus, a physical system (an observer) is not likely to imprint anything that did not yet happen, and hence the inner space of the observer might seem to be essentially finite, limited by the past experiences. Any trajectory in the representation space must break at the "present moment", so that all we have is the memories of the past. However, as soon as there is certain regularity (conveyed by the term "homogeneity"), we can shift the reference point to one of the previous instants, thus obtaining both the future and the past. A generalized view of homogeneity does not impose any restrictions on the character of motion; the only uniformity we need is the very ordering of events, so that one of them goes before another *on the same trajectory* regardless of the reference point. Now, for each past "point" on the track, we have some continuation, and there is no way to determine how long it will last as long as we consider only local experiences. A photon does not know that, a moment later, it will be absorbed by an atomic electron, and the present state of an electron does not imply any further change (or annihilation). In this sense, the homogeneity of time makes it *locally infinite* (extrapolated by homogeneity); of course, various "catastrophic" events (meaning the end of one track and the beginning of another) will violate homogeneity thus introducing relative finality of time. As all the objects in the world are finite, there is always some "end of time": real objects do not live forever, and the corresponding frames of reference are limited; however, in a *local* picture, each frame of reference is infinite in time. Formally, any singularity means a higher-level event, a transition from on local picture to another via a global view. The notion of homogeneity is obviously applicable to the spatial dimensions as well, with the same dialectics of infinity and singularities.

In general, a trajectory in the observer's inner space does not imply any measure of time; it is nothing but pure sequencing of events. However, the very presence of such an elementary hierarchical structure will also introduce the idea of *transition* from the previous state to the next, however adjacent. A transition *does not* belong to the same representation space, though it can sometimes be represented by an intermediate state. In other words, a transition is an element of a higher level, so that the *state* of outer motion becomes represented by a hierarchy of inner transitions. In the simplest case of the mechanical motion of a material point, one could picture it as the transition from one spatial point to another; such transitions can be represented by the vectors of displacement (lying in the tangent space). In quantum mechanics, we consider transitions between the points of a configuration space; quantum transitions are represented by special operators. Event tracks and transition sequences can often be considered as the dual representations of the same outer motion; however, this duality holds only in the regions of homogeneity, while the presence of singularities (global events) makes the two levels essentially different.

Now, a sequence of outer events is represented within the observer by a (static) track in the representation space (frame of reference). Due to homogeneity, all we know of time is local ordering, and there is no idea of *duration*, which must be essentially non-local, comparing at least two different points on the same trajectory. One could be tempted to associate duration with transitions, which are also connecting one position to another; however, this program won't work, since transitions only provide a kind of *spatial* measure (or *distance*), characterizing the difference of *events* rather than their temporal spread. The only way to introduce a measure of time is to compare one track with another serving as *a clock*. That is, we need yet another level of hierarchy allowing of a global view on separate sequences of physical events within the same reference frame.

When the events on some trajectory are associated with the events of the clock process, the distance between the reference events ("clock ticks") can serve as a measure of time elapsed between the events of the target sequence, providing a kind of duration. Comparing the distance between the events on the target track with the corresponding duration (the distance between the clock ticks), we obtain a measure of the rate of change; in particular, mechanical velocities can be defined in this way.

However, to efficiently serve as a clock, the reference process must run on a different level of hierarchy (a different time scale), thus ensuring the least interference with the events on the target track. Indeed, if the two sequences develop in parallel, one could treat a pair of events belonging to the target and clock trajectories as a compound event; physically, such parallelism means either the presence of a specific interaction coupling the two events together, or the presence of yet another level of hierarchy synchronizing the two sequences in a kind of collective behavior.

The very act of associating the events on a trajectory with the clock ticks means broken homogeneity. This additional interaction introduces a specific singularity, which, in general, will distort the physical picture. However, if the clock as a sequence of singularities is implemented on a different level of hierarchy, this distortion is equally present in any point on the target trajectory, and homogeneity becomes effectively restored.

The same frame of reference may be equipped with several clocks, assuming a number of different time measures. However, as long as they are associated with the same physical process, these measures will necessarily be coordinated. Still, nothing prevents the same observer from using independent time clocks for different physical processes, thus making them virtually incomparable.

Once again, in physics, we do not need to consider any conscious observers; it is physical processes that are compared to each other. Any temporal effects appear as the interference of different processes, providing the measure of time for each other. For strongly coupled processes, there is no time; temporal characteristics of a physical process are related to the presence of a weak interaction that does not much violate the overall picture.

Basically, the duration of a physical process can be evaluated as the number of clock ticks (acts of measurement) between the starting point and the end. Of course, for closely spaced clock ticks (in the limit of a continuous probing interaction), a corresponding density is to be used. From this perspective, the clock looks like a periodic process (though its period may be largely varying as measured by another clock). To allow such abstract counting, the individual ticks must be practically identical, while remaining well distinct as independent events in the clock process. This contradiction can be lifted in a *hierarchical* clock, with the lower-level cycles (the interval between the adjacent clock ticks) labeled by the phase of a higher-level cycle (a count), which, in its turn, becomes a sequence of countable reproduction cycles from the viewpoint of the next higher level. Within each cycle, the sequence of distinct phases will produce the impression of one-dimensional flow of time. Moreover, as long as we stick to a specific hierarchical structure (one of the possible sets of time scales), the direction from the lowest to the highest levels will establish yet another one-dimensional structure that effectively "pastes" the time flow of different levels into a universal time, like that we find in physics. However, time measurement is originally based on oscillatory motion; in physics, this requires a consistent treatment of any physical system on the same time scale, to make its states physically distinguishable. As the phases over several cycles become confusing, one needs either a statistical description, or a higher-level clock putting different cycles on the different sheets separating them from each other with specific singularities (branch cuts).

From philosophical viewpoint, the picture of hierarchical time, with a linear flow possible only within a higher-level period, is a consequence of the integrity of the world. Since the world is unique, and there are no other worlds (if they existed, we could rather consider them as the parts of the same unique world), any motion cannot be but an instance of the world's self-reproduction (though it may look like infinity for the creatures inside), and therefore all processes are repetitive, in the most general sense. On the highest level, any interaction means the world interacting with itself, and any change is a change within the whole, reproducing the same world in a different way. Since there is no higher level for the world as a whole, all instances of its reproduction are virtually indistinguishable, and the notion of time becomes inapplicable (as well as the notion of causality *etc.*).

With all those parenthetical remarks, let us return to the simple mechanical motion. In each frame of reference, the observer can label all the outer events by the instances of the inner time (not necessarily the same for different observers). If there is a spatially organized physical process, it can be used to establish a spatial grid, a local coordinate system. For instance, take a signal propagating with a speed c_0 in the frame of reference of each observer. We assume that space is homogeneous and isotropic, so that the speed of the dedicated signal is the same in any spatial point and in any direction; since we have nothing else to compare with, we cannot detect non-homogeneity and anisotropy anyway. Now, consider an infinite company of observers (the clones of the same observer) situated in different spatial points without moving relative to each other; this ensemble makes a frame of reference proper. Each observer informs the others about at any local event by sending a standard signal (presumably carrying some information about the kind of event). In this case, the distance from the current observer (the origin of the coordinate system) to any other is measured by the time (measured by the inner clock of the current observer) needed for the signal to come. For instance, the current observer can send out a signal and receive responses from all the observers on its way. The time delays $2\Delta t_0$ thus obtained will form a spatial scale $x_0 = c_0 \Delta t_0$. It is convenient to assume that these coordinates can be encoded in the signal (for instance, in the amplitude, frequency, or phase shift), so that any signal from a distant stationary observer carries information the unique spatial point. Similarly, one could suggest a synchronization procedure, so that the time variable would be the same all over the reference frame. In other words, the current observer (situated in the origin of the coordinate system) can receive information about any distant events marked by their spatial coordinates and a global time stamp.

Now, the current observer (in collaboration with the statically positioned colleagues) is ready to describe mechanical motion. Let some object move in the current reference frame, passing the current observer at local time $t = 0$; as it passes an observer located in a different spatial point, the current observer receives a signal informing about this event, with a delay $\Delta t_0 + \Delta t$, which readily gives the velocity of the outer motion as

$$v = c_0 \frac{\Delta t_0}{\Delta t} .$$

That is, we can only measure observable velocities relative to the reference speed c_0; there is no way to determine any absolute values unless we get yet another standard signal that could serve as an independent measure. Exactly the same holds for the observer moving at a constant speed v relative to the current observer: in his own frame of reference, the standard signal propagates with the same speed c_0, and all the other velocities can only be measured in the units of this standard speed.

This circumstance leads to a number of obvious corollaries. Thus, velocity measurement is only efficient at $v < c_0$; otherwise, the motion becomes apparently discontinuous approaching a stochastic mode, so that, instead of a moving particle, we observe a statistical distribution. This obviously means that the space and time scales bound to the reference speed c_0 are no longer enough to resolve the details of motion, and a shift to a different level is needed. This is a close analog of the well-known fact that, to resolve a spectral structure, we need a probe of a smaller wavelength (higher energy).

On the other hand, since velocities are measured in the units of the reference speed in all the frames of reference, the law of velocity addition is to be modified, to normalize the sum to the same fundamental constant c_0; in any case simple arithmetical addition of velocities will no longer be valid. Indeed, a reference frame is an inner space of the observer, and other observers can never get any information about its organization except through some outer communication. Since any velocity is measured in respect to a particular reference frame, it is an inner value that cannot be directly summed with similar values obtained in other reference frames. One needs first convert the inner value into an outer equivalent, and then convert it back to the inner value of another observer, to add to another inner velocity. In general, this is a nontrivial transformation, since the structure of the inner space does not need to exactly reproduce any outer structures. Although some correspondence (uniform for all observers) is required anyway, the methods of measurement may significantly influence the result. The usual relativistic law gives

$$u = v + u_0 \frac{c_0^2 - v^2}{c_0^2 + u_0 v} = v + u_{\text{mod}} ,$$

where u_0 is the velocity of a body for the observer moving relative to the current observer with the constant speed v. That is, to allow direct addition of velocities, we need to modify the value measured by the moving observer in a rather complicated manner.

This indirect interconnection of the frames of reference is immediately related to the constancy of the speed of light. Indeed, since we measure velocities relative to the velocity of the standard signal (for the present, this is the speed of light), the propagation of this reference signal will always be mapped into the reference frame as motion with unit velocity, regardless of the actual speed in the outer world. Even if the signal emitted by a moving observer carried information about the coordinates and time of emission, to allow any comparison, these values determined in the moving frame should first be converted to the frame of the current observer, which would effectively restore the unity of the reference speed, at expense of the modified notions of collocation and simultaneity.

Relativistic physics will certainly be valid and experimentally confirmed as long as we stick to “covariant” interactions essentially related to light. This absolute validity is ensured by the logical circularity involved in any interpretation. On the other hand, always remaining within the relativistic world, we do not even know where to look for any physical effects violating the symmetries imposed by the apparent constancy of the speed of light. One could believe that there is no way at all to detect such peculiar effects, and hence we are bound to eternally (within our local notion of eternity) stay covariant, leaving the other possibilities to some hypothetical creatures outside our observable Universe. Still, the philosophy of unism inspires hope, asserting the universal cognoscibility, the ability of reason to assimilate any aspect of the world. It is quite possible that physics beyond relativism is all around us, but we are not yet aware of the fact.

Among the Wise and Crazy

Philosophers have always irritated scientists with idiotic questions. Somehow, they are never satisfied with simple answers like “Oh, this is a trivial property of quasi-holomorphic convolutions of the bundles of Cayley algebras over the filters of residual catastrophes, in the Bayesian limit”. No, they would ask again “But why do you think it should specifically be Cayley algebras?”—“Well, just because enveloped categories are octonion-valued. Everybody knows it”.

Scientists are practical and solid; they have lots of things to discover, and even more things to predict. They have developed many useful tools that are very helpful in serious research since we do no longer need to unfold the whole from scratch, as the basic principles have long since been agreed upon, and it is the specific details of the observable behavior that are of real importance. The rapid development and the spectacular success of science are much due to this ability to accumulate experience in an exponential manner.

Philosophers are nothing like that. Instead of taking things for what they are and steadily extending the range of assimilated phenomena, they just want to know what that all means, and why it is that way. Instead of trusting the already acquired notions and proceeding to more complex cases, they turn to the primitives every time they need to consider a quite familiar problem, with reinventing the whole philosophy as if it had never existed before. Instead of plain and unambiguous decisions, they stay oblique and elusive. That is, instead of producing answers they produce questions. And then, serious people have, instead of discussing the important issues of anthropic landscapes on a 13-brane, to resort to a sort of queer gesticulation in order to bring the overall impression of something to those who don’t understand the sheerest basics of supergravity and cannot tell cis-variation from trans-mutation.

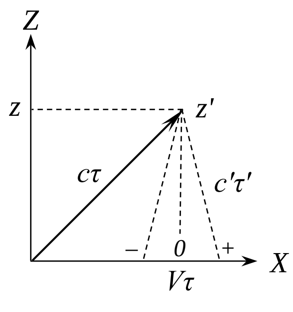
Every course of theoretical physics starts with a brief exposition of the variation principles used to derive the equations of motion and other dynamic features. This is a well-established approach that has proved to be universally applicable and productive; physicists have employed it for a few centuries. For an ignorant philosopher, the usage of variation principles in physics will always remain an unintelligible mystery, a technical trick beyond any reasonable comprehension. They ask why is it that we should believe in the stationarity of the action in respect to the possible infinitesimal variations. The primitive quasi-animistic explanations of the founders of the classical mechanics are not enough to convince a modern person (unless this is a physicist). Mere postulating the fundamental principles is hardly tolerable even in mathematics, and that is why mathematicians have never stopped probing the foundations of their science. So, why? Is there any *physical* sense in the variation procedure, to make it scientific method rather than scientific prejudice? And what if we do not stick to stationary manifolds but rather consider dynamically shaped motion? Is there a kind of higher-level dynamics to regulate the transitions from one stationary world to another?

The general question about the applicability of variation principles would specifically touch upon the scope of variation. Traditionally, physical motion is treated as spatial motion (in a many-dimensional configuration space), and we vary the positions, velocities or accelerations of the moving points. However, a physical system is also characterized by a number of physical *parameters* that do not enter in the general variation scheme, though their variation could essentially change the character of motion. For example, the mass of a material point is used to keep intact in the traditional variation principles, nothing to say about fundamental interaction constants (which then appear to be not so fundamental, in view of the possible renormalizations). However, nature is not obliged to keep the structure of the Universe stable for our convenience. *All* the physical characteristics could vary in real motion, and hence be subject to variation in a theoretical model. As an act of absolute arrogance, we could even assume the possibility of varying the fundamental mathematical constants like π and e. Why not? Mathematics is an abstract reflection of a certain manner of our doing things in the real world; quite probably, in some yet unknown sphere of reality, essentially different ways would be needed, and the very notion of mathematics would change.

Finally, any variation principle at all (either differential or integral) is essentially *nonlocal*. The very possibility of comparing simultaneously taken trajectories (however infinitesimal) assumes their presence *as a whole* within the same reference frame. One can only wonder how it happens that we can derive local physical theories from such nonlocal considerations. This objection is probably not so serious for classical mechanics (which does not restrict the notion of simultaneity) and quantum theories (as they are nonlocal by their nature, taking the whole configuration space as a given construct at any instant); however, in a relativistic approach, the possibility of comparing the points of space-time separated by a space-like interval provokes doubts in the overall consistency. A similar (though possibly not as thorny) issue is related to the possibility of relativistic thermodynamics. Any statistical theory is based on the (at least principal) comparability of the parts of the system within the whole, regardless of their spatial or temporal separation. A consistent relativistic statistics is therefore to be restricted to small systems with inner changes being much slower than the relaxation speed; otherwise, any local motion would destroy the integrity of the system and break the statistical regularities. But this requirement is obviously equivalent to considering slow, non-relativistic movements. Somehow, we need to combine the two levels of consideration, with relativistic motion "embedded" in a classical frame, or conversely, a classical system moving fast as a whole.

A whole bunch of silly questions is about the frames of reference and relativity. For instance, what is the nature of a reference frame? Does it correspond to anything real in the physical world? Or, is it rather an artificial construction, just to describe the way we treat the world in our practical activity? In other words, does it refer to a physical system or to an observer? This problem is closely related to the question about the structure of the reference frame. Thus, in the latter case, all the systems can be placed in a single frame and therefore always remain comparable; on the contrary, there is no reason to admit the similarity of reference frames associated with different physical systems, albeit of the same kind. One could also think of some intermediate possibilities.

For instance, do we need to assume the orthogonality of the spatial axes in all the frames? If the frames were the inner constructions of the observer used to map the observable events, universal orthogonality would be a reasonable choice, characterizing the type of observer regardless of the objective (physical) behavior. However, in this case, the meaning of the relative motion of different observers is an open question, as the individual reference frames cannot be directly compared, hidden inside the observers (the frames themselves are not observable). On the contrary, if the axes of a coordinate frame are physically constructed (by the observer or any other physical system), they must be subject to changes due to the relative motion of the reference frames. Thus, let observer (frame) S' move in respect to observer S along the X-axis common for the both observers (save for the variable displacement of the origin), with the speed V; now, let observer S' construct the Z'-axis as the trajectory of a standard signal (a probe) propagating with some speed c' perpendicularly to the X'-axis. For the stationary observer S, the propagation of the probing signal (possibly with a different velocity c) will no longer be orthogonal to the X-axis, as shown in the picture:



When the probe arrives to some point z (in τ seconds, or billion years), the position of the moving observer on the X-axis of S will depend on the balance between the speeds c and V. In the traditional relativism, the origin of the frame S' in relation to the frame S will come to the point 0 right below the destination point, so that the observed axis Z' will remain perpendicular to axis X'. But it may also lag behind, as in the (–) point, or run ahead, as in the (+) point; in such situations, a moving reference frame will no longer be orthogonal for the stationary observer.

Of course, such void speculations have nothing to do with physics, since the validity of the relativistic picture has been confirmed in tons of experiments, and there is just nothing to discuss. But a philosopher will always ask why.

Yet another philosophical idiotism questions the meaning of the well-known Lorentz transform. The independence of the speed of light of the motion of the source is an experimentally established fact; so, what is the problem? However, considering the correspondence between the coordinate systems in a moving frame and a frame at rest, a philosopher finds it strange that the law derived from the constancy of the speed of light happens to be singular, effectively dividing the whole space-time into mutually isolated regions. How this could happen, if we considered the coordinate systems defined on the whole space-time within each frame, without any exemptions? And how, within a particular frame of reference, we could introduce coordinates in the regions that are physically inaccessible? The situation cannot be improved with the admission of strictly local coordinates, since we still need to attach a whole Minkowski space-time at each point of the physical manifold, but such a global structure, even treated as an inner space of the point, is incompatible with relativistic covariance. In view of that all, the very assumption of the three spatial dimensions is already highly problematic.

To add confusion, a philosopher would object that the constancy of such an obviously non-covariant characteristic as three-dimensional velocity should be laid in the basis of a covariant (relativistic) theory. One could expect that the fundamental quantities of a theory should be defined in a manner consistent with the structure of the theory. That is, a value that is not generally preserved in the transition from one reference frame to another can hardly be physical enough to pretend to the rank of a fundamental constant. Though we can always tweak the velocity addition law to preserve this particular value, it looks much like an *ad hoc* solution, and one would keep wondering, if there were other, more consistent possibilities.

From the logical (philosophical) viewpoint, the singularity of the Lorentz transform does not imply the impossibility of faster-than-light motion. Well, we cannot (so far) get through the light barrier; but what is somebody (or something) is already moving faster than light in respect to earthly observers? In the own frame of reference, this object will be at rest, and nothing prevents it from living a full-scale physical life. Though humans do not exist for such a hypothetical observer (as faster-than-light objects), there are many other objects that move with under-light velocities in this reference frame, and a variety of observers reproducing the structure of the observable world of a human. The whole world thus becomes a cell structure, with each cell isolated from the others by the light barrier, but otherwise a quite traditional physical reality, as far as its inner motion is concerned. Since the principal question of philosophy is about the integrity of the world, the unity of the cell Universe must logically be established through a different kind of interaction (essentially nonlocal from the relativistic viewpoint) that would allow some physical manifestations of the isolated worlds within each other. Quantum physics suggests exchange effects for an obvious candidate. Thus, if all electrons are physically equivalent and one can always be replaced with another, the electrons of the separated worlds could enter the same antisymmetric collective state, and exchange effects would link one world cell to another. In this picture, light barrier is just like any other quantum barrier, and it could be penetrated by ordinary particles, with some probability. Nothing prevents us from picturing any other channels of cross-barrier interaction.

The nature of space and time has fascinated philosophers for centuries, and they invented all kinds of metaphysics to derive the well-known facts from sheer abstractions. Thus, the dimensionality of space was among the favorite "hard" questions, until physicists, to stop further speculations, just said that there is no any fixed dimensionality at all, and the number of spatial dimensions can be arbitrarily chosen to satisfy the needs of yet another theory of everything. We live in a 3D version of the Universe, and this is nothing but a coincidence, a broken symmetry; it is legal to ask how it should be broken to allow the existence of the humanity, but there is no reason why. It simply *is* that way, and we have to merely accept it as an actualized possibility.

Still, the geometrical topic is almost inexhaustible, and those who like to roam their doubts will always find a sticking point. For instance, one could attack the very analytical method, and get deeply astonished by the standard vector structure of space. Indeed, why do we chose a quadratic form for the distance? In mathematics, there are other kinds of metric, and the adherence of physics to one particular form is at least strange. By the way, in economy, we can simply sum up the costs of quite different origin, and there is no need for vector addition. The traditional structure of the physical space seems to hold only in the vicinity of some equilibrium point, with the usual coordinates referring to the departure from the balance (with the linear terms cancelling out).

The very notion of a spatial point is already a cause of trouble. In physics, all the meaningful concepts are finite; the physical world does not know any infinities or infinitesimals. This means that phenomena of very different scale cannot be treated within the same physical theory. In particular, a spatial point of one level may correspond to a whole space on another. In principle, this relation can be mutual, so that a lower-level point is also a contracted form of the upper-level space. For a common example, recall the duality of canonic variables in classical and quantum mechanics. Each point of a manifold is equipped with a tangent space, while each point of the tangent space is a class of trajectories in the base. The philosophical part begins when the possible depth of such hierarchies is in question. Metaphorically exploiting the existence of compound systems that behave as a whole in respect to some outer interaction, one gets interested whether the spatial points could be treated as such collective effect rather than a fundamental primitive. Of course, the same problem with the instances of time.

However, time is a much more mysterious entity. Its dimensionality, relation to space and the lack of isotropy (referred to as the arrow of time) is a permanent attraction for void curiosity. Stubbornly opposing the relativistic union of space and time, philosophers would anyway ask why such unification could be possible. Presumably, an explanation would indicate the limits of this picture, the practical situations where the qualitative difference of space and time would be essentially irremovable. In a way, thermodynamics and nonlinear dynamics suggest the notion of irreversible and non-uniform time. However, such overall behavior is still a superstructure of the usual physical interactions that are symmetric in time. But what if the asymmetry lied already in the vary grounds of all?

In our everyday life, time is always associated with some repetitive activity. The higher is the repetition rate, the faster runs the corresponding inner clock. Entirely in correspondence with relativistic physics, more effort is needed to speed up the things; time is thus subjectively related to energy. The hierarchy of inner time closely resembles the hierarchy of time scales in physics. Here comes an ignorant philosopher with the same silly questions. Why do we think that physical time can be associated with a single number, all physical existence labeled by the positions on the same time axis? Why not admit that time is essentially relative, different time scales not necessarily being comparable? This would be quite analogous to the cell Universe implied by the singular Lorentz transform, with the same interconnection issues.

In any case, the very treatment of time along with the spatial coordinates is not at all a decided thing for a philosopher. Despite all resemblance, there is a significant difference, whether we talk about the *state* of a physical system (its configuration), or its *motion* (a sequence of states). One can certainly introduce the notion of *the state of motion*; but that would be a different level of hierarchy, and its *projection* into the lower-level configuration space is only possible in some special physical conditions. Even allowing for such possibility, we still cannot *directly* map time to the configuration level, though this could be achieved associating time with a particular kind of motion and then comparing the state of that reference process with the accompanying changes in the system's configuration.

Holding that in mind, one would wonder whether it would not be more reasonable to first sort out the inter-level projections, before trying to pack time in there. To be specific, take the two adjacent levels: spatial positions and momenta of material points. Traditionally, the current state of the system is determined by the collection of positions and velocities (which virtually allows us to guess for the next set of positions, while a prediction of new velocity values additionally requires the knowledge of accelerations, and so on). From the dynamic viewpoint, momenta are preferable over velocities in the characterization of the system state (which, by the way, raises the question about the static mass momenta as primary to mere spatial positions). The difference of the adjacent in time system states is then characterized by the collection of spatial displacements and the infinitesimal change of momenta (a displacement in the phase space of the system). Time itself is out of the scheme, as it refers to the overall *scale* of the system's motion, the level of detail we take into account. Including time in the construction of any invariants (like in the structure of the relativistic interval) is therefore equivalent to the explicit specification of the scale, that is, the assumption that the system cannot evolve in its motion to get from one level to another, or rearrange the entire sequence of levels. In a more general approach, we would rather consider the trajectories in the phase space and seek for symmetries in this extended space; this would provide a natural basis for considering dynamically broken symmetries (as we do, indeed, in nonlinear dynamics). In this picture, the scale of time would the derived from the state of motion rather than rigidly built into the theory. For example, the presumably invariant interval could be constructed from both spatial coordinates and momenta, as something like

$$ds^2 = \kappa^2 dp^2 - dx^2 .$$

Now, let dp and dx contain two components of very different scale: a smooth (almost inertial) trajectory on the higher level and very fast circular motion on the lower level, with the radius much smaller than the "macroscopic" displacements. In this case, we approximately obtain

$$ds^2 = \kappa^2 m^2 a^2 dt^2 - dx^2 ,$$

which readily suggests the idea of a reference speed $c^2 = \kappa^2 m^2 a^2$ resulting from some hidden periodic process; obviously, the validity of thus obtained "relativism" is restricted to the domain of stability of that inner motion. Moreover, the presence of a number of oscillations with very different frequencies will naturally introduce a hierarchy of time scales.

All right, let us move on to spoil the feast of general relativity as well (or as malignantly). The fundamental principle of the equivalence of gravitational and inertial mass leads to the formal equivalence of gravity to inertial forces, that is, the apparent forces that act on a mass whose motion is described using a non-inertial frame of reference. The idea seems physically attractive, since there physical motion can never be free in an absolute manner (otherwise, we could never learn about it), and one can never tell an inertial frame from non-inertial. In classical mechanics, inertial forces are considered as fictitious, while general relativity treats them as real physical forces akin to gravity (which allows, for instance, considering the emission of gravitons by a rotating body; sooner or later, we're going to catch such gravitational waves, just because we want it so much).

But now, a stinky philosopher comes in and (with a wry smile) congratulates us on becoming true dialecticians in establishing the fact that the motion under the action of an outer force is indeed free motion! A good piece of work, isn't it? On the other hand, general relativism means that there is no longer any distinction between an experimental result and an artefact; all results equally go. In a higher dialectical sense, this is quite an achievement, an appreciation of the fact that any observation depends on both the thing observed *and* the observer. That is, human actions develop in the real world, and whatever we do is bound to reflect some objective features possibly worth studying. A blunt error of an experimentalist, who, for instance, has incidentally swapped the polarity of power supply, could lead to miraculous discoveries; a mathematical error in processing the results could be a sign of some intricate interdependence between the physical phenomena and human psychology, while any effects of the finite digit capacity in a numerical simulation would indicate indeed a universal physical regularity.

Then the same philosopher would spitefully ask how the physical reality of non-inertial reference frames is to comply with special relativity. It may seem that, for instance, a rotating observer has to admit asymptotically infinite velocities (and an infinite inertial force to keep the world turning). One does not need any astronomic distances: for an observer, sitting on the hard disk of a computer in New York, the whole Europe is already in the far tachyon region. When I turn on my computer somewhere in Moscow, all the Americans are to experience a huge gravitational shock, and I just don't know why they have not yet been entirely exterminated (in God we trust!).

Of course, the philosopher will never swallow the standard answer that any reference frame is defined in a local manner, and it cannot be extrapolated to infinity. This explanation does not clarify the issue, since it the criteria of locality remain vague and arguable; moreover, the existence of any cut-off value for the spatial distance is an additional (and rather strong) physical assumption (virtually equivalent to the discreteness of space-time). Yet another standard explanation that there is no such thing as an absolutely rigid body and the outer regions of the Universe will rotate slower than those in the vicinity of the observer is also rejected with disgust. Indeed, the rotation of the observer is their personal problem, and the rest of the Universe won't much care for it, unless the observer is heavy enough to produce a significant effect on the structure of the whole Universe. But this effect is never taken into account when we simply switch from static Cartesian to a rotating coordinate system, practically in no time (as the very possibility of transform is based on considering the two coordinate systems in parallel). When a ballerina performs the standard 32 fouettés, she immediately *sees* the whole world to spin around her, though the light from the Sun has to travel to the Earth much longer than the whole performance. How this *apparent* motion is related to *real* forces is still an open question. A philosopher could only accept the equivalence of gravity and acceleration as a manner of expression, a witticism, a play of words, rather than a physical principle. Yes, the forces in an accelerated system can add up *as if* there were some additional source of gravity. It *does not* mean that the nature of the additional force is the same as the nature of gravity; it only indicates that, in an accelerated frame of reference, one cannot *directly* measure gravitational effects, requiring certain formal manipulations to account for the observer's acceleration. This is exactly the same procedure we use in astronomy to derive the physical movements of the celestial bodies from their apparent motion relative to a local observer placed at some geographical point and measuring time with a locally calibrated chronometer. Similarly, we cannot use a barometer to measure the altitude unless we know the current atmospheric pressure at a reference level; and even then, to separate the value of interest from the incidental influences, we need to account for the profile of humidity and the distribution of wind velocities, along with any other observation conditions.

In the popular (and even philosophic) literature, there is much enthusiasm about the equivalence of mass and energy, presumably discovered by Einstein. In fact, Einstein has never really established anything like that; he only found that the relativistic motion of massive bodies requires accounting for the velocity of the body in a way that *looks like* the increase of mass for higher velocities. This apparent behavior says nothing about the nature of body's mass as such (the rest mass). The only logical conclusion one can draw from relativistic mechanics is that that a physical observation can never produce any *direct* evaluation of a body's mass, requiring additional procedures to extract the quantity of interest from experimental data. But, again, this is a common characteristic of any measurement at all, and one does not need to be a physicist to become aware of that circumstance. For instance, the common electronic bathroom scales (at least the economic-class models) will display a significantly higher value if loaded abruptly, with a jerk; that is why one needs to apply the weight gradually, avoiding any additional push. Using the "relativistic" logic, one could interpret it as the equivalence of mass and momentum…

Following the same line of reasoning, a philosopher would risk to raise a huge wave of indignation and contempt declaring that, in special relativity, the Lorentz transform does not imply any real equivalence of space and time; it only means that the observable space and time do not coincide with the formal coordinates used in relativistic mechanics and hence these latter cannot be (at least) *directly* measured. The statement does not seem too strong, compared to the entirely traditional convention that spatial coordinates and time in quantum field theory are not observable at all.

Silly remarks of that type can proliferate to infinity. Experimental procedures are extremely vulnerable in this respect, as they depend on numerous factors difficult to track. On these grounds, some theoreticians declare that physical theory does not depend on experimenting at all, and no experiment can influence its inner truth. Some philosophers object that a physical theory is meaningless without any practical implications; on the same footing, they spoil the reputation of experimental science questioning its objectivity and precision. Thus, the traditional statistical methods leave a philosopher bewildered and perplexed. Why do you think that averaging should increase the accuracy and objectivity of observation? Even if it does in many practical cases, this is not the reason to believe in its universal power. Any statistics is based on a number of assumptions; the random nature of fluctuations is possibly among the strongest. Even accepting the probabilistic picture, one still needs to guess the type of statistical distribution, which may essentially depend on the range of phenomena to study. Everybody knows that experimental results may contain systematic errors (with their own distribution of fluctuations). In most cases, such influences cannot be eliminated or reduced. Experimentalists usually do their best to detect the source of error and purify the results applying all kinds of mathematical processing; however, this makes the result essentially indirect and less trustable in the context of theory validation. There is always a suspicion that the intricate methods of "normalization" applied to experimental data serve, in fact, to impose an *a priori* theoretical model, so that, instead of *studying* nature, we *adapt* it to our conceptual preferences. Such an approach is all right in engineering, as long as we can keep control over the critical parameters. In science, it may seem too biased and possibly misleading.

In any case, there are different directions of research. Mostly, we are interested in general laws that hold on the average. However, one can also be interested in the individual manifestations of these laws in the infinite diversity of real situations. A deviation from a mass regularity is as objective as the regularity itself, and a closer look may bring insights into entirely new aspects of the application area. For example, a general theory of literature may be interested in the typical forms and the common trends; on the contrary, in the work of an individual writer, the characterization of the individual style is often much more important that the traces of all kinds of tradition and the influences of a certain literary school. Once again, we come to a hierarchical picture, with a qualitatively different science on each level.

Luckily, scientists rarely listen to philosophers; and they are certainly right. As one of my physics teachers used to say, all the questions "why?" are sheer demagogy. If you ask a scientist, why it comes to this or that particular choice, the answers would largely vary:

— Because everybody does it that way.
— Because it's cool, and I like it.
— Why not? Just to see what happens.
— Because I need to feed something to the peers to get published.
— Because I want to sell it to the DOE for a grant.
. . .

The right answer is "I don't care". It is not up to a scientist, to ponder upon the reasons of scientific research. Let scientists do science—and philosophers do the rest.

Global Relativity and Relative Locality

In the popular literature, it is often indicated that a relativistic observer is local. However, for a philosophically minded person, this is a rather strange kind of locality. Thus, we are said that measuring distances requires determination of two spatial positions at the same time, while time intervals are only meaningful in the same spatial point. To be sincere, this is a logical circularity, an implicit manner to postulate the invariance of the interval.

Physically, to consider two spatial points "at the same time", the observer must be much larger than the distance between the points, so that their separation would seem practically infinitesimal. Similarly, to take two instances of time "in the same point", we need to assume that the duration thus measured is practically negligible; otherwise, it would at least some motion within the instrument and hence spatial displacement. The orders of infinity must be correlated in a very special way, to achieve the desired result, which results in yet another logical circularity.

In these circumstances, a formal axiomatic introduction of relativity seems to be more consistent, albeit lacking physical justification. Relativism thus becomes an *ad hoc* construction; but is it much different from any other physical theory?

Well, what's wrong with the assumption that we can measure time locally, in the same spatial point? For a local observer, measuring distances will then require a travel from one spatial point to another; of course, the observer does not need to travel in person, as one can send and receive signals. This innocent statement contains an inner contradiction, as it takes for granted the possibility of probing signals of a negligible energy, so that they would not much influence the motion of the physical bodies and the state of the observer; however, small energy transfers mean large durations (both in quantum and classical mechanics), which may violate the locality of time measurement.

Here is the cheat trick. Travelling in person, we make our frame of reference essentially non-inertial, as we need to undergo some accelerations to start travel and turn back (to measure the local duration of the travel). In exactly the same way, a beam of light can be treated as an organ of observer that must be manipulated to reach the target and return to the starting point. For instance, a photon might be simply reflected by the target, to run back to the origin; but this necessarily involves momentum transfer, and hence the presence of physical forces. One could invent all kinds of intricate arrangements to circumvent the reflection scheme. Imagine an active media that sends a photon to the observer every time the object of interest (a probing photon) passes each spatial point. In this case, one could believe that there is no energy loss, and no deflecting forces. However, the very act of triggering the emission of the tracking signal by the medium requires a kind of interaction between the probing photon and the medium, just to make its passage noticeable. This is equivalent to photon absorption and re-emission, which means non-inertial behavior anyway, nothing to say about the inevitable time delays. Add here the energy cost of detecting photons in the origin point, where the observer must interact with the probing particle to determine its parameters relevant to the act of measurement.

Physics is an art of approximation. In real life, we can indeed stage certain kinds of experiments assuming the non-perturbing nature of measurement. Thus, in classical mechanics, the usual energy transfers due to the act of measurement are much smaller than the energetic scale of the physical process to study. However, today, we know it for certain that this approach does not directly work in many cases of interest. For instance, microscopic particles (as well as highly correlated macroscopic systems) feel any measurement as destructive and essentially changing their state (or the state of motion). This could be compared to a superheated liquid (or an overcooled gas) that would burst at any fluctuation. We avoid this difficulty restricting the nature of measurement, limiting ourselves to the asymptotic region far from the physical interaction zone. In this region, we presumably can destroy the outgoing particles without any considerable effect on the interaction history.

There are strong reasons for the region of very high velocities to be yet another problematic case. In our relativistic vision, any energy transfer (or the effective mass of the interaction carrier) increases with approaching the light barrier, so that no probing interaction could be considered as negligible. In terms of general relativity, this also means the presence of a mass that essentially distorts the geometry of space-time and makes motion non-inertial. That is, for very high speeds, no measurement can be considered as non-disturbing, and the overall scheme of special relativity theory fails. Since general relativity is postulated to be locally the same, its applicability near the light barrier limit is as questionable. Thus, popular physical theories undermine their own foundations, and it is a matter of sheer luck that they happen to be largely practical.

Still, let us imagine an idealized case of an observer (a physical system) who would be able to determine local time and operate with probing signals somehow avoiding such delicate issues. How could spatial distances be measured within a frame of that kind? For a spatial segment (a very rigid rod) at rest, we could sit at its center and emit photons towards the both ends. Registering the time needed for reflected photons to return to the origin, we multiply it by the speed of light (which is presumably the same regardless of anything) and thus calculate the distances. In this symmetric case, we effectively (or admittedly) apply the ruler simultaneously at the both ends of the segment, by the very setup of this mental experiment.

Now, let the segment move with a constant velocity along the axis. In this case, sitting in the origin, and emitting the probing photons at $t = 0$, we receive the reflected signals at different instances of time separated by a measurable duration Δt. It looks like that, if we knew the length of the segment, we could (with certain "natural" assumptions) derive its velocity in this reference frame from experimental data. Conversely, knowing the rod's velocity, we can derive its length (relative to the static observer). But there is no way to determine the both from the same measurement. A very familiar situation, isn't it? Quantum mechanical indeterminacy thus shows up in classical motion once again.

The situation gets even worse, as we can never be sure that the temporal discrepancy we detect has not been produced by a mere lack of symmetry, an initial displacement of the segment relative to the static observer. A rod at rest shifted along the X-axis can produce exactly the same Δt as a moving spatial segment. Moreover, receiving the reflected signals at the same time, we could as well assume the motion of an originally displaced segment, so that the two kinds of temporal discrepancy just cancel out. There is no way to distinguish spatial asymmetry from non-zero velocity in this experimental setup, which is yet another aspect of the intrinsic interdependence of space and motion.

As a result, the principle of locality is violated in such measurements anyway, since we can never guarantee that we are not comparing the distances from the observer taken at different instances of time. Once again, there is an implicit introduction of a global frame covering all the physical events of interest, so that the whole sequences of such events could be treated in a structural way, as coexistent at any moment (of a higher level). In experimental physics, data aggregation is universally popular, starting from mere statistical estimates, and up to complicated digital processing. All such procedures are obviously inconsistent from the formal viewpoint, but their practical acceptability speaks in favor of the idea of an essentially nonlocal character of nature, as reflected in physical science.

For example, take the same scheme of "radar" measurement to determine the position of a point by the time delay between the emission of the probing signal and the reception of the reflected signal. The very consideration of a point out there, away from the observer, is already nonlocal, since it assumes a finite distance present at any single moment; regardless of any quantitative estimates. Further, we take for granted that the point is moving relative to the observer and hence yet another nonlocal idea, a trajectory (possibly contracted to a single point) described by the parametric equation

$$x(t) = x(0) + vt \ .$$

Similarly, the trajectory of the probing signal is a nonlocal entity described by the equation

$$x(t) = c(t - t_0) \ .$$

At some t_x the two trajectories intersect (if ever), and the reflected signal travels back to the observer (in the assumption of the constancy of the speed of light) along the trajectory

$$x(t) = c(t_x - t_0) - c(t - t_x) \ ,$$

to arrive to the origin at

$$T_0 = 2t_x - t_0 = 2\frac{x(0) + ct_0}{c - v} - t_0 = \frac{2x(0) + (c + v)t_0}{c - v} \ .$$

Since there are two unknown parameters, $x(0)$ and v, we cannot tell much from a single measurement. Now, if the next probing signal is emitted at $t_1 = t_0 + \tau$, we get

$$T_1 = \frac{2x(0) + (c + v)t_0 + (c + v)\tau}{c - v} \ ,$$

and the velocity of the moving particle is readily evaluated from aggregated measurements:

$$T = T_1 - T_0 = \frac{(c + v)}{c - v}\tau \ ,$$

$$v = c\frac{T - \tau}{T + \tau} \ .$$

Obviously, by construction, thus measured speed of the point will always be less than the speed of light (otherwise, the intersection of the trajectories would become problematic).

A similar version of this technique would employ the registration of light emitted by the moving source rather than probing signals. This modification is extremely popular in astronomy, where most information about the motion of the deep space objects comes from Doppler shift measurements. However, in this case, we do not know the exact period (wavelength) of the emitted signals, and we need to adopt additional assumptions about the physical nature of the emitting system. Thus, we must be sure that the frequency of the emitted light does not depend on the kinematic and dynamic conditions, or introduce the appropriate corrections where such dependence might be important (like in the case of the "transversal" Doppler effect due to relativistic time dilation).

This is how formal manipulations help us to "extract" physical information from measurable quantities. Sometimes, it may be difficult to convincingly draw a distinction between "extraction" and "introduction". No theory can justify such tricks; it is the practical applicability that always has the final word. Just imagine a different kind of nature, a nonlinear world, where the distances do not add up in the usual way, so that the sum of two lengths x_1 and x_2 would be given by a nontrivial function:

$$x_{12} = f(x_1, x_2)\,.$$

Similarly, the definition of velocity may as well be nonlinear:

$$\boldsymbol{x}(t+\Delta t) = \boldsymbol{V}\boldsymbol{x}(t)\,,$$

where $\boldsymbol{V}$ is a nonlinear (and possibly nonlocal) operator acting on the position vector (which can be no vector at all, with the addition law as above).[2] All the logic of measurement is then to be revised, to produce quite different estimates. Of course, we respect the correspondence principle; but the correct asymptotic behavior can be achieved in an infinity of ways. The typical problem of overextrapolation is due to the common illusion about the abstract nature of mathematics apparently independent of the application area. However, the admissibility of that particular kind of mathematics, or any other, is a practical question, a decision to take, which is of primary importance in the development of any theory. If we add one quantity to another, we must be sure that these quantities could naturally sum up, so that the very operation of addition would have a practical implementation. That is, the formalism of a science is closely related to the ways of action; in particular, any meaningful theoretical result must be interpretable in material terms. For instance, when we formally solve an equation via a suitable variable substitution (in the parametric form), we employ the knowledge of the physical symmetries that are really present in the system and reflected in the structure of the original equation. Treating them as purely formal, we only indicate that they are not yet of interest for the present study, but this does not mean that they could not come forth in a different context.

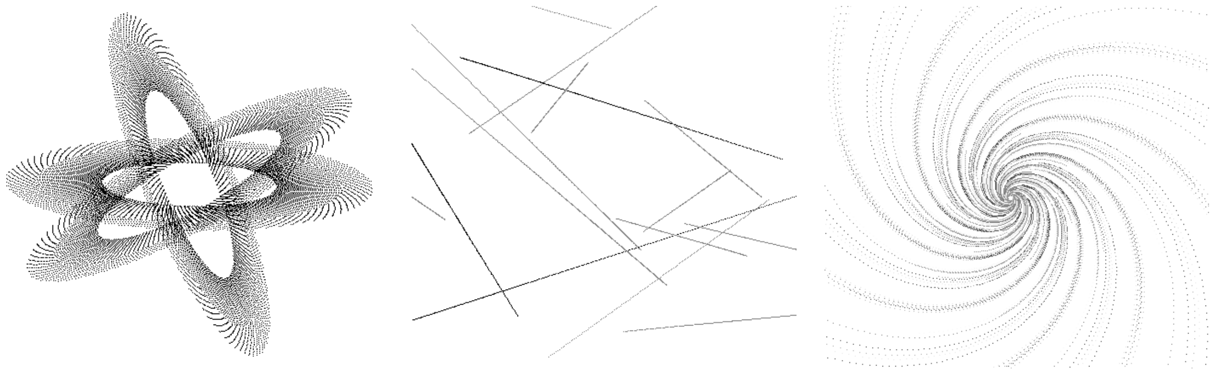
Returning to the issues of (non)locality, we must conclude that, in any measurement, there is a local model of a nonlocal world, and we use that model to map the observable events. We admit that the resulting picture reflects the structure of the real world out there. That is, using our (presumed) knowledge of the world's dynamics, we can restore its state at any instant as long as causality prevails over stochastic features. This state is absolutely nonlocal, but, in this sense, it is certainly measurable. The logical contradiction is complete: the assumption of locality leads to a nonlocal view of the world.

A stubborn physicist would proceed inventing all kinds of conceptual appliances to eliminate nonlocal dynamics from fundamental science. From the philosophical viewpoint, it is evident that all such inherently fallacious attempts will eventually get stuck in contradictions. There is the only world, and everything that happens belongs to the same Universe. The very separation of an individual thing from the rest of the world means that the thing's environment becomes as definite and hence can be reflected in (represented by) that very thing. The degree of the "inner" and "outer" definiteness is exactly the same. That is, every local feature will have a global counterpart, and no physical description is

[2] One can even admit that, in some physical systems, there is no such operation as a temporal translation, and hence the very notion of velocity is inapplicable. For instance, a trajectory may arise as a statistical feature (a kind of attractor), with no local congruence at all.

possible without a good portion of nonlocality. As there is no way to drive it out, it's not worth the effort and we'd better occupy ourselves with the problem of control. Once consciously admitted and recognized, the level of nonlocality is a perfect indicator of the scope of the model.

As everybody knows, nonlocal behavior is basically related to the formation of compound systems incorporating many local components. The characteristics of collective behavior depend on the lower-level motion in a *nonlinear* manner, and this makes the adjacent levels of hierarchy *qualitatively* different. Take the simplest case, the purely mechanical motion of a number of material points with a central interaction (an obvious source of nonlocality). Two bodies rotating around a common center of mass is a typical example of a compound system, and the traditional approach separates its inner motion from the motion of the center of mass representing the overall motion with a linear combination of the corresponding position and velocity vectors. However, this linearity gets broken as soon it comes to any additional interactions. The compound system will only interact as a whole with the bodies far away from the position of the center of mass; that is, for distances much greater than the typical diameter of the couple, and on the time scale much slower than the rotation period. Moreover, even without any other bodies, the very act of observation puts the whole system in a spatial and temporal context imposing an "artificial" structure on the measurement results. Thus, for a "localized" observer with an observation window much smaller than the inner motion scale and the registration period much less than the period of rotation, the motion will be apparently stochastic, while an infinitely large (adiabatic) observer will see a single point moving in an empty space; of course there is a whole range of intermediate cases. A numerical simulation for a simple 2D oscillator provides an illustration of this "imposed" pattern formation due to a limited field of view (see the figure below).



In this line, we must admit that the unity of the world means a universal nonlinear entanglement of all the things and events, and any physical structure is to be unfolded in accordance with the structure of the current activity. As a result, the hierarchy of human activities determines a hierarchical vision of the physical world. A frame of reference is, in general, an instance of such a hierarchy.

Now, we come to the problem of comparing different frames. Formally, one needs a hierarchy of frames, so that the frames to compare could be placed together within the same higher-level frame. Objectively, this assumes a common activity, with the same object and product for a number of active subjects (which, of course, do not need to be mere individuals). Taking physical experimenting for a class of such reference activities, the only way to compare different observers is to make them report on the same physical process. This task is not as trivial as it may seem. It requires, at least, a certain idea of "sameness". The two observers must agree on a range of physical events they can see together. Thus, if some event takes place for one observer, but is absent for the other, there is simply nothing to compare. On the other hand, to be comparable, the common events must be viewed from the same angle. If one observer is interested in the body's trajectory and the other in its temperature, they have no news to exchange. In view of the abovementioned duality of length and speed, one could also doubt the possibility of comparing the qualitatively different (complementary) aspects of the same. Thus, a moving observer can certainly determine a rod's length, in its own frame of reference where the rod is at rest. The static observer could take the length thus reported for the reference in the velocity measurement scheme, as above. In this case, two complementary measurements would be enough to completely specify the state of the physical system. As the relativistic theory suggests, this is not so. That is, aggregating data from different sources is a risky operation that may produce spurious results.

This problem has long since haunted the science of astronomy, which often deals with slow processes to trace over many decades, or even centuries. Astronomical observations are known to depend on many factors, and the method of raw data processing is of crucial importance. Astronomers have developed intricate protocols of reporting, which allow to adjust a huge bulk of earlier observations to a newer value of some basic parameter, thus introducing the necessary corrections without the need of overall revision. Of course, there are influences that cannot be formally fixed; nevertheless, much of the relative movements of the celestial bodies can be kept as a trustable evidence. However, for an extraterrestrial observer, such a detailed account might be of no value unless there is an objective procedure relating one reference frame to another.

We can never tell for sure how the others see the world. We may trust their observations, but their reports picture the world from an unknown perspective. Any comparison requires a number of strong assumptions, reflecting our ideas about the way we act as well as the way the others react. But here is where science ends. At any instance, we perceive the world but not our own perception. The observation of the way of observation is a *different* kind of observation. As soon as we try to incorporate reflection in physics, we come to a complicated non-deterministic (if not mystical) picture. Still, everybody knows that science *is* possible, and that it can be very efficient. Why?

Once again, the answer is practical. Any science studies some portion of reality inasmuch it has already become an object of a common activity. All the preceding experience that has eventually led to establishing such a commonality is outside science. All kinds of methodological considerations used to "scientifically" extrapolate the past experience into the future are outside science either. It is no use to ask a physicist to explain physics; physicists *do* physics, and they should (and would) rather ask somebody else if they ever needed any explanation. To compare the frames of reference, physicists employ the commonality of physical events that has been *practically* established. In other words, they do not *admit* anything—they only act as admitted. This is the primary nonlocality built in any physical theory.

When it comes to the foundations of science, we are free to choose the level of consideration according to the current practical needs. That is, among the infinity of assumptions, one selects only those that are the most likely to vary, and the activity of systematization is only to provide a platform for further revision of the system; in reality, the fundamental principles are always formulated from the viewpoint of a (preliminarily) reformed theory.

Like in any hierarchy, the structure of a science is mutable, subject to hierarchical conversion.[3] Even within a very limited task, the substantiation of the principle of relativity, there are multiple choices, and different opinions may equally go. Thus, inertial frames of reference were once preferred as avoiding "non-physical" forces and clearly indicating the "basic" dynamics; any accelerated systems were treated as auxiliary and purely technical means. However, since there are no interaction-free systems in the real world, the notion of an inertial frame of reference has gradually evolved to an abstract idea, while any real frames should necessarily contain some kinds of "fictitious" forces due to the complex character of the motion of the references frame. As long as we hold to a local description, there is no way to tell a "spurious" effect from a "physical" interaction, since neither frame is preferable in an absolute sense, and one can only speak about the classes of dynamically similar frames interrelated by "inertial" transitions in a general sense, not restricting ourselves to the constancy of the relative velocity. The different classes of "inertial" transitions are characterized by their key invariants. For example, the laws of mechanics take the same form in all the frames moving with a constant velocity relative to each other, which is the most commonly known kind of inertial motion. However, if we consider the total energy (or an equivalent temperature) as an essential physical parameter and hence a required invariant, such uniform translations can no longer be considered as "inertial", as they mean an increase of the kinetic energy due to the motion of the system as a whole.

[3] P. Ivanov, *Philosophy of Consciousness*. — Trafford, 2009.

It is not quite clear, whether the criteria of inertial motion may include various statistical characteristics. Such parameters are often dynamically asymmetric, so that the transition from one frame to another cannot be "undone" by the inverse transition. Still, non-commuting operators have long since become a habitual feature of quantum field theories, and the constructs like temperature or pressure field do not much differ from a distribution of masses or electric potential. In a way, any physical quantity at all is statistical, as any physical notion (like any notion at all) refers to a class of the possible "microscopic" implementations rather than a unique pure state. With all that, the meaning of relativity remains disputable. Is it physically acceptable that the body's temperature in one frame of reference raised while falling in another frame? And what about the entropy? Cain killed Abel—or maybe the other way round?

However uncomfortable, the ghost of universal mutability is going to haunt science in any realm and for all times. This is the price we pay for deliberate locality. Even admitting a kind of global criterion to sort out our current impressions, we do not exorcize the evil, since the very distinction of the lower and higher levels in a hierarchy is limited to a specific conversion, a particular unfolding. The behavior of a crystal depends on the properties of the atoms and molecules; however, the atoms and molecules in a crystal behave differently from the same atoms and molecules in a fluid or a plasma flare. A brain of an animal is functionally different from the brain of a social animal, with the identic physiology. Similarly, the local motion of a material point in a given frame of reference could as well be considered as a manifestation of the very way the reference frame is constructed and introduced.

So, let's take it easy and never care much about any exhaustive explanations. The predictions of science should be treated with a grain of humor. There is no reason to get scared by our own imagination. Science is great at suggesting us plausible ideas of what could be done. But these ideas remain sheer abstractions until somebody really does it (often in a way very different from the originally predicted). And, of course, no science can prevent us from doing "wonders", however impossible they might seem from the scientific viewpoint. A new science will come and lift traditional restrictions. We cannot tell in advance, which impossible things are to become possible in the nearest future; but we may be quite certain to get some, and so without end.

Yes, in real life, one cannot live by mere wonders. Otherwise, they would not indeed be wonders. This is the same issue of the local eggs from a global hen. As soon as we get a workable solution for a class of practical problems, we'll do our best to develop the relevant science within the chosen conceptual framework (which is a kind of reference frame too). Virtually, this is the only way to reach the limits of its applicability, where we could start exercising our magic power once again. Meanwhile, philosophy is just a funny toy and a source of consolation when a problem turns out to be really hard. So, once again, what can be said about our local dwellers of a mechanical world, with their clocks and lightning probes?

The model of a reference frame assumes that different observers are all "embedded" in a higher-level formation distinguishing them by a set of *global* parameters (for instance, relative velocities). One could argue that these velocities are not really global, as they are measured by one of the observers and hence depend on the current (local) frame. However, the principle of relativity suggests that the observer "1" moving in some reference frame "0" will see exactly the same picture, with "0" moving with exactly the same relative speed in the opposite direction. This symmetry is treated as an important physical feature, but it does not follow from any local considerations.

Further, each observer is deemed to have the complete information on whatever happens in his own frame of reference at any instant; that is, a local observer is absolutely global within the rest frame. This is a very strong assumption, but it is always implicitly made. Basically, this means that a reference frame is something quite definite, an instant structure tractable as a whole. This, again, puts a reference frame in a higher-level context, making it a point in a global sense.

Since comparison of reference frames is primarily a higher-level operation, the corresponding observers do not need to be aware of each other and of their relative motion. The interrelation between the different frames of reference is therefore *objective*. Nevertheless, nothing prevents a local observer to interpret a moving object as another observer and picture the world from that hypothetical observer's viewpoint. This *subjective* (local) relation may differ from the objective law, as the lower level structure does not immediately reproduce the peculiarities of a higher level. Local comparison is, in fact, a three-step procedure: first, we guess for the global representation of the both frames, then we compare them in an objective way, and finally, we need to project the result back into the local frame. In physics, we often forget about the first and third stages and treat our local theories as objective laws “discovered” in (and “confirmed” by) the empirical data. Note, once again, that (re)constructing another observer’s view of the world is different from the local description of that world; these are quite different activities, and the possible correspondence between them cannot be explained by any local considerations.

It seems natural to stick to the same structure of the reference frames for all the observers. As one observer cannot immediately see the world by the eyes of another, one is bound to use one’s own ideas to express what the others might fancy. In other words, we make the observers clones of each other, acting in the same manner and representing the results in the same abstract forms. However, such a universality is yet another global feature, and, in general, this requirement could be weakened on a higher level. On the other hand, an apparent local discrepancy between the reference frames may be (at least partially) spurious, resulting from the transitions from the local to the global description and back, with much simpler inter-frame relations on the global level. For instance, on a higher level, the equations of motion could be exactly the same for different observers, while taking a much more complicated form in the local frame of each observer, involving a number of “inertial” forces. The same structure of the local reference frames would only mean a regular relation to the higher level. On the other hand, due to hierarchical conversion, the very distinction between the “horizontal” and “vertical” relations in a hierarchy is relative, and the procedures of folding and unfolding the hierarchy are not unique. The identity of the frames of reference is, therefore, to select a consistent hierarchy of hierarchical structures.

It is an open question, whether physical space and time could be treated in a global manner on some level, while remaining relativistically entangled in local observations. The correspondence principle and the traditional asymmetry of spatial and temporal dimensionality speak in favor of such an idea. Yet another indication of the same could be recognized in the instances of “hidden” relativism, when certain properties of a classical (macroscopic) system can only be explained by some inner (quantum) relativistic effects. That is, to produce an observable picture in a local reference frame, we need to transform the higher-level (global) space and time selecting one of the possible rules; the collection of such rules represents a physical symmetry, which does not necessarily depend on the relative motion of observers. Since each observer can independently vary the parameters of the symmetry group, the pictures of motion in different frames are not necessarily correlated. The transforms of special relativity result in a very special case of “cloned” frames, related to each other through some global parameter. This closely resembles the idea of “quantum entanglement”, in purely classical motion. Conversely, the explanation of quantum correlations could be related to a layered nature of motion.

Just to conclude, let us ponder a little over a few potentially problematic issues in comparison of reference frames. For instance, a typical illustration of special relativity compares the observation of the motion of a spatial segment (a rigid rod) by two observers (inertially) moving relative to each other. If the rod is at rest for one of the observers, we conjecture that the other would see it as moving with a (presumably) constant speed.

In this setup, the very idea of an extended body violates strict locality. To perceive the rod as a whole, both observers must somehow learn about its existence and identify its two ends with the same object, then agree on that the two observers speak about the same thing… Quite a program for a local observer, who (ideally) does not see anything beyond his own location and who cannot measure but time delays. Still, scientists are most resourceful to do things like that. Otherwise, we would know nothing about far Universe, where our spacecraft has not yet arrived. As well as about the microscopic world, where we’ll never arrive. Practically, this requires a series of independent measurements along with an intricate interpretation procedure based on some general theoretical picture. In our mental experiment, we have to assume that all the preliminaries are over, and the vision of a space segment as a physical object is given to the both observers “by construction”.

Still, the possibility of any common events remains questionable. Thus, admitting that both observers use the same probing signals to arrange the points of their reference frames, we cannot be sure that they do it in the same way, unless one observer could directly observe the procedure of measurement as performed by the other.[4] That is, we have to compare the very acts of observation along with the resulting relative pictures of motion, which obviously gets us back to the hierarchical vision of a reference frame. However, in reality, we rarely observe the very propagation of light (though, theoretically, it can be made visible, in some very special media). Of course, we do not mean various phase effects, like the visible motion of a shadow, or the march of the dawn over the globe. Normally, we only detect light emission and absorption, which are the natural candidates to the collection of comparable physical events. With all that, using strictly collimated light signals (narrow beams), one observer would miss a signal sent by another observer in the opposite direction, and the commonality of the probing signals would be ruined. To override this difficulty, we could assume that probing signals are spherical waves, and they can be detected at any angle. In a mental experiment, we do not care for the practical feasibility; in real life, the limit cases of extremely weak and extremely strong signals could raise questions about the applicability of the approach. Of course, a wave (and a spherical wave in particular) is an essentially nonlocal entity, smelling the confusion of a classical and a quantum description once again. From the logical viewpoint, we implicitly introduce a very strong assumption that any reference frame occupies the whole physical space (while remaining an inner space of the observer). In this global relativity, we can catch any signals regardless of the direction of emission; somehow thus obtained information becomes attributed to the same spatial point (the location of the observer), making it local (and hence relative). The same logical background is to cope with the influence of the hypothetical faster-than-light motion on the range of common observations.

A complementary logical issue is brought about by the idea of a spatial direction. How can we determine directions locally, in a point? Even with infinitesimal displacements, we need to leave this point and get back. A vector thus becomes an abstraction of a cyclic path, a very special case of nonlocality. On the other hand, time measurement is wholly based on comparison of cyclic processes; a typical clock is an essentially nonlocal spatial device, and we always decide on time using a spatial distribution. To isolate this nonlocality from the rest of the physical system (which could then be deemed to be local), one might employ dimensional separation, and hence the inherent nonlocality of spatial directions. In a way, the origin of the relativistically entangled space-time is due to the relative nature of spatial orthogonality.

Considering light emission and absorption (sending and receiving signals), we come across yet another problem. How can we know that the photon we receive here and now has come from a faraway object that has sent it long ago? This is an essentially global idea that does not follow from any local measurements. As all photons are like each other, there is a risk to confuse one object with another, and get a distorted picture of reality. In practice, such issues are resolved by repeated and prolonged observation; if they reproduce approximately the same picture from one measurement to another, we conclude about the existence of some outer objects that produce the observable effect. No scientific notion (and virtually no notion at all) refers to an individual measurement; we first obtain an overall picture and then extract the details of interest as the qualitative feature of the whole. Of course, such averaged pictures can eliminate important physical effects and introduce spurious dependencies. To check their validity, we need to compare data from many independent sources employing alternative physical mechanisms. The simple scheme of cloned observers using the same measurement techniques to obtain the same global structures (reference frames) is therefore physically meaningless, or, at least, heavily restricted. To put it otherwise, a frame of reference is a kind of collective effect, with many nonlinear (global) interactions resulting in a relatively stable formation on a higher level of hierarchy.

[4] Similarly, one observer could construct a model of the other's frame of reference directly comparing the motion of the physical bodies with observed motion of the other observer. The indirect way of doing the same is to employ the other observer's reports as a source of information, just in the manner we use light emission and absorption to judge on light propagation.

Energy and Information

Originally, physics is about things that happen without any human intervention. Though we often trigger some physical events to do something practical, the physical part of it still does not depend on our intention, and we need to adjust our expectations to the objective laws rather than force nature to behave as we expect.

On the contrary, information exchange is all about human communication. Though it may seem to happen regardless of the human will in the electronic devices and computer networks, the purpose and primary source of data exchange is always related to some human needs, albeit in an indirect manner. Without this cultural background, one would merely have random physical processes in the interconnected circuits, but no information flow, unless the circuits develop a kind of society of their own, a robotic culture. As one of my colleagues put it, “Beats me. Why do we calculate heat production in the server room using the total power supply value? With all those heaps of information processed every moment and stored on disk, shouldn’t we spend at least some energy on computing proper?” Still, from the physical viewpoint, computing is nothing but a complicated way of heat production. Storing either a “0” or a “1” in a memory unit takes exactly the same energy, and any meaningful interpretation of the resulting physical structures are beyond the computer. This is like a mechanical balance being entirely indifferent to what exactly we are going to weigh, a nugget of gold or a morsel of food.

Information is the deliberate order of things rather than in things themselves. The same physical state can carry a valuable message and become meaningless with the last possible interpreter gone. Similarly, the letters in this text may convey my ideas to another sentient being, but they will remain a void occurrence, a random sequence, if there is nobody to share or oppose this particular viewpoint.

However, as long as we keep aloof from any mystical speculations, we must admit that arranging things to support informative communication requires some physical effort, and hence it will eventually dissipate some energy. No information exchange is possible in a conservative system assuming no heat production. That is, to put something in order, we need to bring disorder elsewhere. In thermodynamics, this idea is reflected in the concept of entropy, and physicists agree that total entropy can never decrease in an isolated physical system. Considering this circumstance, one is tempted to interpret any changes in physical entropy as communication thus introducing information as a physical property. This is a trivial logical fallacy: if information transfer requires entropy flows, it does not imply that any entropy variations at all are due to information exchange. On the same footing, one might directly relate muscular strength to the quantity of food.

Under certain conditions, entropy can serve as a measure of information; in other cases, some alternative (for instance, financial) measures might be more appropriate. Reverting the logic, one could introduce a kind of entropy on the basis of the chosen information measure and develop a thermodynamic picture of communication and information processing. The commonly known Penrose’s fiction of quantum consciousness thus tried to reduce psychology to physics. A sober-minded approach would take such scheme transfers for what they are, mere metaphors—sometimes useful, sometimes not. Within physics, one encounters numerous metaphors of the same kind, like negative temperatures, or backward motion in time; everybody knows that such figurative expressions refer to regular physical phenomena that can as well be described in a more rigorous (though possibly more complicated) way, with the temperatures always remaining positive, and time preserving its intuitive monotony.

It is important that quantitative measures of information are not necessarily what we really need; there are situations when a qualitative description would be much more accurate. Thus, we can discuss the moral aspects of communication, characterizing a message as misinformation or deliberate lie. We can mention the timeliness or completeness of information, or speak about its integrity and acceptability. There is no need to numerically assess anything unless there is a socially established scale accounting for subtle gradations. In many practical cases, numerical estimates remain mere labels that could be equivalently replaced by common words or pictograms expressing the same in a more obvious and easily comprehensible way. It is a standard principle in experimental science that, to avoid spurious regularities, the precision of calculations should not exceed the precision of the initial data; the same principle must certainly be respected in theory as well, meaning, in particular, that we shouldn't give numerical answers to qualitative questions, for all the quantitative part would be utterly excessive in that case, provoking an illusion of knowledge more precise than it really is.

Returning to the necessity of physical motion for human communication, one could wonder if there is a lower limit to the quantity of energy required to enable information transfer. The existence of such a threshold seems to be rather plausible, especially in the view of the quantum world, with all its discrete-spectrum and resonance phenomena. However, recalling that any discrete features in quantum physics are always embedded in a continuum (as there are no absolutely stable states in a compound system, and the maximum we can get is just long enough lifetimes, possibly comparable with the age of the Universe), we could admit as well that any energy threshold for informative communication was due to the character of constraints imposed on the communication channel rather than an inherent property of communication as such.

For instance, in quantum computing, the commonly accepted Landauer principle states that the processing of 1 bit of information implies energy dissipation of at least $kT\log 2$, with k being the Boltzmann constant and T denoting the absolute temperature. That is, with huge data flow in modern computers, this minimum energy consumption, however small, becomes quite measurable. Today, we are already approaching the level of efficiency where this "physical" limitation would start to play.

This reasoning, again, hides a few logical pitfalls. If we treat a computer as a physical system, all we can expect is heat production, without any relation to information transfer. The Landauer formula refers to an elementary quantum transition, a kind of electron spin projection sign flop. One could call such a system a binary switch and discuss its physical properties in length. Even in this physical picture, the presence of the lower limit is entirely due to the statistical nature of the process, assuming an ensemble of "free" binary switches that do not interact with each other or with their physical environment. In a strongly correlated system, the energy cost of an elementary flop may be lowered (this is usually referred to as "coherence", or "entanglement"). The appearance of the Boltzmann constant in the Landauer formula is in no way accidental; it implies physical constraints "selecting" a specific physical model.

On the other hand, computer operation does not need to have anything in common with human communication and information exchange. This is (basically) a physical process synchronizing the states of many binary switches (usually far from being elementary). Of course, on the physical level, it does not matter, what the computer is exactly doing; the same profile of heat (and entropy) production could be obtained in many ways. To come to computing proper, we need to leave physics in the background and consider the "logical" level of the same system, which is a quite different science. A physical system does not care whether this or that particular state of a binary switch stands for "0" or "1"; the ideas of "bits", "bytes", "words" *etc*. are entirely alien to physics. That is, when Landauer says that the erasure of one bit needs certain energy, this is an eclectic mix of two different statements, the first referring to the states of a physical system (a binary switch), and the second admitting that these states can be *interpreted* in terms of computer operations. This interpretation is a special activity, based on a different physics, *on a different energy scale*. That is, somebody (or something) must *read* the current state of a binary switch and trigger a number of child processes depending on the result. For a classical computer, the energies involved in interpretation and commutation are negligible compared to those needed for switch operation. In quantum computing, interpretation may significantly interfere with switching, thus introducing *quantum logic*, in addition to quantum physics.

Of course, there is no need in a human interpreter. A whole hierarchy of abstract active media is provided, for example, by the OSI model. The physical implementation of such agents can largely vary; in this sense, a crystal, an organic molecule, or a living cell could be metaphorically pictured as a kind of computer. The traditional communication theory is applicable on this level, including any quantitative information measures. However, to be precise, there is no information proper, since nobody informs anybody in this computer world. Computers do not process *information*; they process *data*, the *patterns* of the physical states. The transition from the physical to logical level is therefore analogous to the transition from the dynamic to statistical description in physics, drastically reducing the number of the degrees of freedom; this resemblance provoked the conceptual confusion identifying the quantity of information with negative entropy, but these are two different kinds of statistics that cannot be reduced to each other.

Now, let us turn to information in its original sense, as a meaningful message passed in human communication from one person to another. Mere data transfer is not enough; both data and the very act of their transfer must be *motivated* within some common activity establishing the context of communication. The same physical process, with the same logical interpretation in terms of data processing, can be either informative, or not, depending on the cultural conditions. Is there any lower limit for the energies involved? Both yes and no. Yes, since the material basis of any particular culture is limited by the current, historically established way of production, including a definite level of physical reality. In this culture, we just cannot detect too subtle changes in the state of the world, and hence the existence of a physical threshold in human communication. However, with technological development, the range of observable physical phenomena will necessarily expand, and the economic role of crude force will tend to zero (without ever actually reaching it). The energy levels in a complex correlated system are much closer spaced than in any of its elementary components, with less energy dissipation required for informative communication. As the upper limit for a system's complexity is that of the whole world, there is no absolute threshold for communication energy, and any cultural limitations are to be lifted in the future, in due course. Metaphorically using the Landauer formula, one could observe that, with technological development, information exchange tends to occur at lower temperatures, gradually approaching the absolute zero. The physical meaning of this metaphor can be explained as dominating of controlled behavior over stochastic processes in well-cultivated nature. Indeed, any dynamics obeying some deterministic equations of motion with deterministic boundary conditions could be said to occur at zero temperature; in this sense, human intentionality serves to introduce order in chaos, and that is exactly what informative communication does.

In real life, the situation is somewhat more complicated. Any hierarchy can produce different hierarchical structures (hierarchical conversion), and there is no rigid distinction between any adjacent levels. That is, some processes on the logical level can become mere physical events, and a portion of conscious behavior can eventually be delegated to various “computers”. Conversely, physical systems can develop certain “logical” functionality, while computers may someday form a new kind of society, to complement the human culture. Still, the overall picture remains the same in any particular case, and the principal difference of physical motion from computing is to be clearly understood, as well the distinction of the both from information exchange.

Phenomenology of Space and Time

Today, talks about multiple dimensions and all sorts of exotic spaces do not stir a slightest inner discomfort. We grow accustomed to mathematical abstractions that must replace the simple naive idea of space and as simple feeling of time. Well, let physicists develop theoretical toys. A philosopher is made to never believe in formal banalities, especially when they violate the trivial evidence of our senses. However far from promoting the ancient 3D vision as an absolute dogma for the entire universe, we still need some intuitive consistency, a common base for minute distinctions. That is why it might be useful (at least for a few freaks) to temporarily abandon mathematical monsters for a typically physical (or rather natural scientific) approach, starting from a couple of qualitative observations that could outline the scope of admissible formalizations.

Both scientific and popular literature produce a persistent impression of an epidemic term confusion. If a physical something bears the same name as a mathematical object, this does not mean that physics and mathematics have become one science. Physical space has as little in common with mathematical spaces, as hot dogs have nothing to do with canine attractiveness. In science, we rarely invent terminology from scratch. Any science grows from vague everyday experiences that get gradually sorted out to form an abstract categorization, with the traditional names of most categories hinting to the science's history. When the development of a science gives birth to a new notion, we first try to find an appropriate (that is, intuitively appealing) name from the common language, and if this fails, one might take a random word, or invent a neologism. In any case, it is the matter of borrowing, and different sciences may borrow the same words for different reasons. In particular, both mathematical and physical notions of space go back to the same practical idea, but their identification would be of the same vulgar sort as taking apes for the ancestors of the humanity (or the other way round).

In a way, the mathematical notion of a space is originally a generalization of a physical idea related to our common experience of motion. However, as soon as it becomes a formal structure, it can accept any kind of geometry, topology *etc*., unlike the physical space that incorporates these partial characterizations in a syncretic manner, as the aspects of the whole that cannot be detached from each other and arbitrarily combined. On the next level, physics takes the idea of a formal space from mathematics and substitutes the original physical notion for an abstract structure serving as an *a priori* framework for further research. Nobody cares any longer for objective study of space, nor for its objective difference from time. In effect, this leads to a loss of specificity: physical space becomes indistinguishable from any other feature, since anything at all can be digitalized and thus put in a formal mathematical space. Numbers do not stink. First, we represent some physical entity with a mathematical construct; then we forget about physics and declare that our approximate representations *are* the physical reality itself, and there is nothing else to study.

A similar recurrent fallacy is also haunting mathematics, which is often deemed to be the science of mere designations, virtually identical to its language. However, even very young children know that the word 'chocolate' is not quite as tasty as a real brick of chocolate and every adult perfectly knows that talking of money is far from actually possessing it.

Still, there is a remarkable divergence between physics and mathematics that probably could explain their fundamental role in the hierarchy of science in general. Somehow, mathematics did not yet usurped the physical notion of time, which remains very important in physics, albeit abandoned by many physicists trying to match the mathematical standards of rigor in their essentially non-rigorous science. Mathematics and physics are therefore the principal representatives of two complementary paradigms in science: the static and the dynamic, a *structure* and a *system*. Mathematics describes how the world is made; physics tells us how it goes. There is a third as universal paradigm, a *hierarchy* (meaning that, in addition to mere being and going, thins also *grow* and *develop*), but it has not yet been culturally associated with any particular science.[5]

Paradoxically, where there is a single science, there is no science at all. New knowledge comes in comparison; nothing to compare means nothing to learn. That is, trying to reduce all sciences to mathematics (or any other universal foundation) is undermining the very idea of science. Paying too much attention to commonality, we neglect differences, which, indeed, constitute the content of knowledge as such. There is nothing exciting in demonstrating how mathematical physics can be, or in saying that chemical reactions are based on the physical properties of atoms and molecules; it is much more interesting (and challenging) to show which aspects of physics make it different from mathematics, or to observe the principal difference of chemistry from physics, of biology from chemistry, of psychology from physics and physiology. And that is exactly the purpose of phenomenology, to outline an object area before and in spite of any formalizations. It is only in this way that we can indicate the real scope of an abstract theory, and thus the possible alternatives, the promising (from both scientific and practical perspective) directions of research.

As soon as one has acknowledged the importance of a phenomenal view, the problem of space and time can be critically reassessed. Of course, all such assessments are very selective, never pretending to any exhaustiveness; on the other hand, compete science is dead science. To come to a physical picture

[5] The idea of development is outside science as such, since any science deals with the already established regularities and never with what is yet to come. Still some sciences may better than others represent this aspect of reflection. For the nearest approximation, one might fancy an essentially practical science, with theory directly linked to experiment and observation, like a kind of computer modelling (artificial intelligence) relieved from too much piety towards its mathematical foundations and physical implementation. Social sciences might as well contribute to the establishment of the developmental paradigm.

of the world, we must put together many individual pictures and let them interact, to produce a higher-level integrity. This is the physical way of doing things.

So, here is a sample outlook. In the following, the words ‘space’ and ‘time’ refer to physical space and physical time respectively, unless a different meaning is explicitly specified.

1. *Space and time refer to the motion of material bodies.*

Any physical system is primarily a number of material things interacting with each other. That is, to remain in the domain of physics, we must consider any objects as outer to the subject, regardless of how they may participate in human activity. Of course, many physical things we deal with have been made by humans; however, in physics, we do not speak of their origin, we describe their motion as independent of the creator and the observer, assuming that the same behavior will occur whenever a similar physical system comes to existence, regardless of whether humans constitute a part of the system’s environment or not. We intentionally exclude any subjective elements reducing them to the conditions of motion and constraints. A physical effect observed in humans or animals must as well be observable without humans nor animals (that is, we can always find natural systems exhibiting that kind of behavior, or develop a technology to produce the same effect in an automated way). For example, if some features of brain operation seem to be due to the presence of a new physical force, the same force must be found outside any brains, acting in an objective way. Otherwise, we can only conclude that the already known physical forces sum up to produce the impression of a new force, *as if* it existed in the brain. Similarly, in atomic physics, we describe holes in atomic shells as independent particles interacting with electrons, thought, in fact, there are no real particles, and the observable picture can also be obtained considering electron correlations (which, however, may be much less elegant).

There are other ideas of space and time that do not directly involve any physical motion. Thus, psychological space and time are different from physical space-time, though, of course, any psychology is only possible as a superstructure of some physical motion. Similarly, some space- or time-like features can be discussed in history, in logic, or in computing, but their relation to physical space and time may be very distant and obscure.

2. *Space and time are objective.*

Referring to objective motion, they are themselves independent of any human interference. When physical bodies move unobserved, they remain the same bodies, and the spatial and temporal characteristics of their motion are preserved. There is no physical motion beyond space and time. Consequently, a physical description of space and time must allow their natural existence, deriving any observable features from nature, and not the other way round.

3. *Space and time are determined by the character of motion.*

Strictly speaking, this character just manifests itself as space and time. The traditional picture of something moving *in* space and time is but metaphorical. The objectivity of space and time is of a different kind than the objectivity of material bodies and their motion. Space and time do not exist as separate entities; they merely are the objective aspects of material motion.

However, physical motion may have aspects that do not directly correspond to its spatial and temporal character (and this poses the problem of additional specification). A particular study may focus on such secondary features, but this does not entirely remove space and time from physics, which provide the necessary background to further consideration. Thus, describing an isolated physical system as a whole, we do not need the details of its inner motion or its spatial position (which is formally expressed as the homogeneity and isotropy of space). Similarly, in the case of stationary motion, we do not need to track minor changes, rather observing an overall pattern; any attempts to delve into the process of its formation would introduce a certain degree of non-stationarity.

4. *Space and time are complementary as the aspects of motion.*

That is, first of all, they are different, and even opposite, though impossible without each other. When it comes to measurement, we may evaluate spatial dimensions using time, or express time in the units of space; this does not mean that spatial and temporal phenomena are physically identical. The very possibility of such interchangeability is determined by the character of motion.

To compare, in mechanics, there is a well-known duality between coordinates and momenta; in a potential field, one can describe motion using either configuration representation or, equivalently, a momentum-space picture. This does not make coordinates and momenta physically the same. In general, any measurement at all will express one physical feature in terms of another. Still, the target system is different from the instrument. The width of a computer screen can be measured using a ruler; but you can hardly make the ruler display this text. Similarly, this text's lifetime is quite limited, but it does not live in the clock.

The separation of space and time is yet another physical problem distinguishing physics from its mathematical slang. This is an absolute requirement for any physical system, which would not otherwise be completely defined. Any relativity refers to the possible formal representations, but never to space and time as such. That is, for any physical system, spatial and temporal characteristics of motion can (but do not need to) be compared to the dynamics of another physical system (a frame of reference), and the result will naturally be different for different reference frames. But the original motion does not depend on the way of its expression, and, in particular, its space and time exist before any measurement, as the objective properties of the system. This means, in particular, that, to correctly reproduce the physical picture, one cannot take just any frame of reference at all; the structure of the frame must be compatible with the objective character of motion. For example, one can speak about the physical equivalence of all the frames of reference that move slower than light relative to each other; any faster-than-light frames are incompatible with such "local" dynamics (which does not mean that there are no other kinds of dynamics that would require a "non-local" frame).

5. *Space and time do not always refer to physical states and events.*

For an outer observer (a different physical system), the motion of any physical system looks like a stream of physical *events* changing the system's *state*. However, this picture will vary from one observer to the next. In particular, the same object can participate in human activity in many ways, requiring an appropriate physical description in each case. Some of such descriptions may include spatial and temporal characteristics of motion, some others won't. For example, a balloon traveler needs to control the temperature and pressure of the gas inside the bag, while a land observer will mostly track the spatial displacement of the balloon as a whole; the two observers will be interested in different kinds of physical events, though both may consider, say, the height of the fly as practically important. Of course, the presence of humans is of no physical relevance. For a photon emitted by an atom, it does not matter, where exactly the parent atom resides; on the contrary, for a free electron, its distance from an ion or atom is of crucial importance, since it determines the character of interaction.

Formally, the possible states of a physical system are often considered to belong to an abstract configuration space, so that any physical process could be pictured as a transition from one configuration to another (sometimes graphically illustrated using a drawing or a 3D model). Though this closely resembles the common vision of space, there is a significant difference. An abstract configuration space can be of any nature; its dimensionality, geometry and topology only reflect the character of the physical interactions involved. Thus, in atomic physics, the configuration space of a helium atom is a complex infinite-dimensional structure, including both discrete and continuous domains; the elements of this space (physical states) could be roughly described as complex-valued (or operator-valued) distributions over an inner Euclidean space, which binds the physical description to the ordinary space-time; however, the inner space does not correspond to any observable displacements, and the inner time (the sequencing of events in the configuration space) has little to do with "macroscopic" time (applicable to the atom as a whole). Though some theoreticians tend to treat configuration space and time as the only physical reality, this approach does not seem too productive in clarifying the nature of physical space-time. Dismissing the problem is not the best way to cope with it.

Sometimes, spatial relations are included in the physical state; in other cases they stay somewhere in the background. Similarly, physical events can be either "real" (that is, occurring in physical time) or "virtual" (of no relevance to the outer behavior of the physical system). In any case, the representation of physical motion with a chain of state changes (events) is relative, and the same motion could be pictured with many different sequences of events, which, in particular, will produce alternative physical theories.

6. *Space and time assume physical interaction but do not entirely depend on it.*

Though space and time express the character of motion, they do that in a very general and fundamental way. Yes, matter certainly influences the properties of space and time. But this is not what most physicists usually mean. General relativity is a bright guess; but we still need to guess what we have really guessed. Equations of motion describe the structure of configuration space, carving out an intricate manifold from the complete body of possibilities. But this does not necessarily influence physical space and time. Indeed, at least within the "standard model", all the physical interactions seem to merely form a kind of superstructure over space and time; they introduce symmetries and constraints that determine the properties of the corresponding interactions, without touching the spatiotemporal background. In particular, special relativity is an expression of the symmetries pertaining to electromagnetic filed, while general relativity is a formal representations of the local symmetries of gravitation. Those who have not yet refused to trust physical (rather than mathematical) intuition will admit that the very idea of space and time comes before any dynamics, as a premise, and not an implication. To bind spatial coordinates and time into the relativistic interval, we first need something to bind. To discuss connectivity and curvature, we need something to connect or curve. In the most sophisticated physical theories, one could still find a hidden substrate of plain space and time (similarly, any abstruse mathematical reasoning goes back to the fundamental primitives like points and junctions).

In other words, space and time represent a kind of relations between material bodies other than physical interaction; somehow, this is related to the very comparison of different things and processes (in philosophy we speak about the types of reflection). A specific interaction obviously assumes a particular way of putting it all together. But there are many interactions possible within the same reflective framework; on the other hand, without being aware of what we thus presume, an entirely different conceptual (and physical) base only could be found by a pure fluke.

7. *Space means identity. Time means distinction.*

Basically, the idea of space includes simultaneity. Space is what can be taken *at the same time*. Conversely, time is what happens *in the same spatial point*. That is, spatial relations connect different things, thus making them equivalent, belonging to the same class (a moment of time). Time makes the same thing differ from itself (this is what we call development).

In a formal approach, this difference disappears, since one can always treat a many-dimensional space as a series of "slices" with effectively lowered dimensionality. In the Euclidean space, a cube can be pictured as an infinity of squares piled on top of each other. This may produce the impression of time, as the points of each square certainly belong to the same equivalence class, represented by the "height" coordinate. However, such a formalism is implicitly based on the idea of motion, actually producing the different layers of the cube by changing the spatial position of a single square with time. Consequently, the time-like behavior of spatial dimensions is a secondary effect, a projection of spatial displacement into space, which hides (folds) the temporal side of motion, but does not eliminate it, merely making it *virtual*. Spatial forms spanned by motion are *not* yet real bodies; they could be compared with the traces of motion on a long-exposition photograph. The very possibility to mentally decompose a real thing into a number of lower-dimensionality layers presumes the existence of higher dimensions, to give room for that particular kind of motion. The complete integration of time with space in modern theoretical physics is therefore an illusion, or, in the formal aspect, a logical fallacy.

The relativity of space and time is usually explained by the observation that, in two frames of reference moving relative to each other, the meaning of "the same point" appears to be different. This formally leads to relative simultaneity, and hence the entanglement of space and time is accepted as a fundamental physical fact. This argument is logically deficient. Indeed, it implicitly assumes the physical comparability of the two frames, that is, the existence of common physical events. Such a common event is supposed to occur in a single spatial point at a definite time, though the numerical representation of this occurrence (spatial coordinates and time value) may vary from one reference frame to another. But a spatial point in one frame does not correspond to a point in another; rather, it corresponds to a trajectory (or a density). A physical event in one frame does not correspond to an event in another; rather, it must be related to a process (or a probability). Consequently, formal coordinate transforms simply mapping one space-time onto another have nothing to do with the comparison of the physical dynamics. To be honest, we need to map trajectories to single points (folding) and single points to trajectories (unfolding). In the hierarchical approach, this is described as conversion of hierarchies.

Any point-to-point transforms are only applicable when *there is a common space-time,* however differently represented in each reference frame. Physical motion is understood as developing in the same space, and temporal sequencing is the same in all the frames. Any differences are of a purely quantitative nature, while the overall physical picture remains intact. This imposes very strong restrictions on the character of interactions in such a system, cutting any attempts to go beyond such a “truncated” reality.

8. Space and time are prior to measurement; interactions produce scales.

Physical motion is objective; it is the same regardless of whether somebody detects it or does any measurements. Of course, we can influence the behavior of some physical systems; but this only means that a wider system must be considered, including the physical effects of human activity. The overall character of physical motion, as described by space and time, is therefore indifferent to any outer (that is, non-destructive) interactions. However, even very small influences may slightly modify the state of the physical system, without influencing the mode of motion. Observing such “infinitesimal” reactions, we can judge about the structure of the system and, in particular, about its space and time.

A detailed study of the effects caused by a standard probing interaction is available for the area very far from physics, namely, the theory of pitch scale formation in music.[6] An admixture of a small local perturbation is shown to result in a global scale allowing to compare distant elements of the whole. The homogeneity of the original system (that is, the possibility of reproducing the same structures in respect to any element) makes this scale quasi-discrete, that is, consisting of a number of separate zones representing the detectable values of relative distance. The number and widths of the zones depend on the selectivity of the probing interaction. Moreover, each scale allows a number of subscales, which do not necessarily coincide with the subsets of the base scale. This hierarchical structure is not arbitrary; it is entirely defined by the properties of the base scale (“embedded” in it).

Though the details depend on the kind of the system, the qualitative picture of scale formation is the same, and one could judge (however metaphorically) about physical space and time in the same lines as about musical pitch.

First of all, we infer that scales are not inherent in the observable system; they are an “artefact” of the mode of observation. However, the possible structures are objective, and, as soon as the type of probe has been fixed, we can only “tune” our perception to one of the available levels. A different kind of probing interaction will produce a different range of allowed scales, possibly incompatible with the others. That is, to define a class of comparable frames of reference, we need to specify the reference interaction common to all the members of the class. In relativistic physics, this role is played be weak electromagnetic fields; the constancy of the speed of light is, in this context, not a physical fact, but rather a specification of a class of physical phenomena we are going to involve.

Further, each scale allows different levels of detail within the same spatiotemporal background. The typical times and lengths may vary; however, the hierarchy of the qualitatively different pictures is not arbitrary, as it is entirely determined by the adopted scale. From a higher-level perspective, any lower-level motion cannot be resolved, and the corresponding physical events happen in the same point at the same time. This justifies the formal method of the traditional relativistic physics as one of the possible levels of description. In addition, we clarify some notions of quantum physics picturing the observable macroscopic structure as the effect of inner (virtual) motion.

[6] L. V. Avdeev and P. B. Ivanov, “A Mathematical Model of Scale Perception”, *Journal of Moscow Physical Society*, **3**, 331–353 (1993).

Finally, in any given scale, with all its embedded hierarchy, we cannot resolve any details at all; there are areas where the current scale is no longer adequate, and we'll need different notions of space and time.

9. Space and time refer to relations between bodies as well as to individual bodies.

Connecting different material bodies, space manifests itself as *distance*; as a feature of a single body, space becomes its *size*. Similarly, two events can be separated by a definite time *interval*; alternatively, any single event has a definite *duration*. The distinction and mutual determination of inner and outer definiteness is one of the difficult problems in philosophy and logic. However, physically, it is obvious that the size of a body can be measured by the distances between its ultimate parts, while the duration of an event corresponds to the interval from its beginning to its end. Conversely, the distances between different bodies determine the size of a many-body system and the time interval between two events determines the duration of the complex event comprising the both. In other words, there is a hierarchy of bodies and events, and the external relations of the lower level get folded in the inner characteristics of the higher. Folding and unfolding this hierarchy is not a mere mental exercise; in physics, one needs a technological solution allowing to practically regroup things whenever needed. If you cannot (at least virtually) bind two things together by some physical interaction, you have no right to speak of a compound system. On these grounds, the promoters of the close-coupling technique in the physics of atomic collisions deny the physical meaningfulness of autoionizing states in atoms and ions, since the resonances observed in inelastic scattering can be described on the lower level, as transitions in the spectral continuum. On the contrary, in high-energy physics, any resonance is treated as an effect of virtual particle formation, a true physical event.

When several material bodies form a compound system, and several events are included in a higher-level event, different combinations are possible. The traditional duality of parallel and sequential composition is, possibly, the most obvious. Thus, a star and its planets form a system with the size much greater than the sizes of the components, while the electronic and ionic components of interstellar plasma occupy exactly the same space. Similarly, a displacement along the *X*-axis can be followed by a displacement in the *Y*-direction or, alternatively, the two evens may happen simultaneously, in parallel. The possibility of decomposition is determined by the character of interactions involved, that is, by the structure of the system's space-time. For instance, to round a city block you have to sequentially pass the two rows of buildings, unless you know a short cut across the courtyards. An example of a less trivial combination can be provided by the multiplexing techniques in computer networks. In general, there is a hierarchy of complementary routes, and the actual choice depends on the system's history.

However, there is yet another possible manifestation of space and time closely related to scale formation. Under certain conditions, physical bodies and events can be characterized in an absolute way by their spatial or temporal positions. To build such a *coordinate system,* we need to select a few reference bodies or processes, assuming that their spatial and temporal characteristics are stable in the relevant range. The practical implementation of such a rigid construction is not a trivial task; in most cases, we only hope that our choice is sound enough; a variety of industrial applications is to justify it or demand a critical reassessment.

Every particular selection of reference bodies and events determines a *frame of reference*. As indicated, different frames are not necessarily comparable; the equivalence of reference frames can only be established in a local manner, for a limited range of physical systems.

10. Space and time can be embodied in physical dynamics.

In philosophy, we find that every individual thing can be made by giving a specific form to some material. Physicists represent the material aspect of the Universe by the notions like mass or energy, while the reflective (ideal) aspect includes, in particular, space and time. However, from the philosophical standpoint, the very distinction of material and form is relative: forms can become matter, and matter can manifest itself as a kind of reflection. Indeed, if there are a few things, each being a unity of material and form, we can use them to make a new thing; in this compound thing, the original things will play the role of material, and hence their form (the ideal aspect, a mere relation between material bodies) must be somehow convertible in higher-level matter. There is no absolute material, and no abstract forms. That is, the motion of material bodies can itself become a material body.

For a modern physicist, this seems to be an almost trivial statement. However, matter is not necessarily represented by mass, and some future theories may need a different (possibly more structured) representation. Still, we can be sure that a similar structure will be discovered in space and time, leading to an extended principle of duality. On the other hand, today, we merely postulate the equivalence of energy and mass, without trying to trace its physical origin. A formal convertibility is not enough. We need to discover the physical mechanism establishing this equivalence and thus indicate its limits and the ways of extension. That is, in the present state, the presence of physical dualities can be considered as a formulation of a problem rather than an answer, and their physical justification is yet to be found.

Just for a hint, let us recall that time becomes dual to energy in the context of some oscillatory motion; the higher is the frequency of oscillation, the greater is the corresponding energy. When there are several levels of motion, with very different characteristic times, the motion of the lower level is hidden from the higher-level observer, and its effect will only contribute to the internal energy (mass) of the higher-level bodies. It seems like oscillatory (repetitive, recurrent) movement is physically more fundamental than the trivial inertial motion, and, quite probably, the world of the future physics will be more like a hierarchy of reproduction cycles rather than a box-like space and monotonic time. This agrees with the general philosophical idea that there is only one all-comprising world; there is nothing else; hence, whatever exists, or whatever happens, can only be one of the possible modes of the world's self-reproduction.

Dazzling Ideas

The history of physics knew many happy guesses that put the whole science on the new track. Of course, the first and most drastic revolution came when people developed the notion of natural regularity that does not require any conscious interference and happen under appropriate conditions regardless of the presence of any sentient beings. The acceptance of this world as it is makes all the rest possible. Otherwise, there is no science. And nothing to philosophize.

It might seem quite obvious that, admitting something beyond human experience, we should be ready to encounter things that are very unlike humans, with all the petty worlds they arrange. However, it has taken many centuries for scientific thought to get rid of anthropomorphic visions in just a few areas of physics, and there are vast domains where anthropocentrism has happily survived the XX century, with fair perspectives for the next. Still, the very ability to fancy the huge outer space swarming with galaxies as well as the hidden infinity of the tiniest perceptible something is an important step forward, towards more theoretical modesty and versatility of viewpoints.

The two greatest achievements of the early XX century, an extended principle of relativity and a generalized notion of observation, have directed the physical science ever since. Though apparently different (and even in conflict), they basically do the same: the objective character of nature is to be expressed in terms of symmetry. The ancient dream of finding "perfect" forms in the foundation of the Universe has thus been echoed on a new level, in a sophisticated mathematical guise.

There is no need to much dwell on how productive this fundamental idea has proved to be. The symmetries of equations and boundary conditions have been directly related to the symmetries of the phase flows; any picture is equally valid, as they refer to the same physical reality. In many cases, important results can be obtained without knowing the details of dynamics, from the overall structure of the model. Relativistic and quantum gadgets have long since become a part of people's everyday life. The Universe has been successfully explained in the scale range of 80 orders of magnitude. Isn't it great?

Unfortunately, bright ideas do not only light up our minds. They also dazzle.

Once having invented a handy instrument, we tend to adapt our activity to the tool, so that the current problems could be solved using the old habits and proven technologies. Our acts become implement-driven rather than purposeful. When all you've got is a hammer, everything looks like a nail. Science transforms into sheer engineering, and there is neither need nor taste for discovery. The question "why?" shoved aside as demagogical philosophy, the only purpose of science is to compute and calculate.

Probably, it's not too bad, as long as enough is enough. The inner inconvenience of just a few should not undermine the mental comfort of many. When it comes to a real social need, a scientific revolution is bound to burst out with all the wild spontaneity of the blind fate. A philosopher might mutter something like that intellectual blindness would not well suit a person of reason… Let them doubt; they do what they can.

Still, even silly doubts may be of some use. At least for the one who doubts. Just because the very presence of a doubt brings some certainty. Thus, one can be certain that there are no absolute hammers fit to nail down the whole Universe. Sticking to one routine, we drive out millions of others. What is good for one may be an obstacle for another. Any theory is only meaningful as a complement to a wider view allowing us to explain what we really mean. Formulas do not explain anything, they only formulate. However, the same idea can be formulated in many ways, while a very different idea may need a drastically new formulation. Trying to reduce physics to a few fundamental principles, we break with physics as such. Science should not postulate nature; science is to describe it.

By the way, for a few centuries, mathematicians have tried to establish the universal foundations of their science. All in vain. Every open door presented more doors to open; answering a question, we raise another one. As a result, we have a number of alternative mathematics, equally consistent and equally lacking justification. Since justifications are never formal.

And now, some physicists try to derive all physics from a mathematical trick. Isn't it silly, to trust mathematics more than it can trust itself?

A few decades ago, there was a wave of formalistic books with the titles like *Foundations of Physics*, *Geometrical Physics*, *Logical Physics*, *Quantum and Other Physics as Systems Theory*, and so on. The authors were very systematic and neatly fit any known physical law in an axiomatic (or numerological) approach of their own. Did that advance our understanding of physical nature? Not a bit. All such inventory work produced mere *ad hoc* constructs, incapable of delivering a fresh idea. Probably they were interesting as philosophical experiments. But never as an insight to physical methodology.

Returning to the certainty of doubt, one could observe that the language of differential geometry dominating in modern relativistic mechanics and field theories is very restrictive when it comes to essentially non-stationary phenomena. Formally, it results in mathematical singularities. For a physicist, a formal infinity would only indicate the inadequacy of standard geometry in the critical region and need for a better formulation. All the talks about physical singularities are mere metaphors exaggerated by popular science writers to the extent of a common prejudice, so that many scientists start seriously believing in black holes and the Big Bang.

It is in the nature of science to seek for regularities, mass reproduction of the same objective behavior. Science never deals with the unique. Indeed, we just don't need science that would not give us a stable platform for common activities replicated from one day to the next. But we also don't need science that would not give us a certain perspective, a range of choices to consciously shape our future. The essential stationarity of a scientific theory is to be complemented with a critical attitude towards the present forms of our knowledge and openness to (if not active search for) any alternatives. The principal goal of science is to develop a bunch of complementary models applicable in the respective regions of stability, while the transitions between the stationary domains remain out of grasp, beyond any science at all. We can find regularities in the very modes of transition and make them the object of science. This will give yet another science, with its limits of applicability and the necessity of alternatives covering the domains out of reach (similarly to the development of nonlinear dynamics). Boundary sciences do not transform one model into another; they only refer to their own (independent) domain, and their formalism cannot be "translated" into any other, even in the asymptotic sense. For instance, thermodynamics cannot be derived from mechanics or physical kinetics, nor interfere with their specific models. These are independent sciences, each following the logic of the respective object area. Similarly, general relativity may fairly well describe the structure of gravitational field relatively far from a very massive object; to describe the interior of that object, we need a different theory (or, maybe, just a different form of the same theory, like the inner Schwarzschild solution); however, to speak of the physics of the regions close to the boundary (which, of course, does not assume any physical singularities), we need something new, unlike the "outer" and "inner" theories.

The necessity of switching to a different model at the boundary of the applicability region closely resembles the well-known physical effect of phase transition. There is no smooth transformation; the very meaning of a boundary is a qualitative change, a leap. On a different level, this boundary may be smoothed, or even entirely disappear; but the very change of level is a qualitative leap, and there is no direct correspondence between the levels.

In a way, quantum physics came to cope with such essentially non-stationary processes involving abrupt changes out of control, qualitative leaps. As we know, quantum theory has only revealed a new kind of stationarity, so that the observable non-stationary effects could be considered as an artifact of level change, a statistical ("macroscopic") aggregation of quite deterministic virtual ("microscopic") transitions. This level fusion lead to the mystical interpretations of quantum mechanics, as if bare human will, mere presence of a human observer, might influence the light from the distant stars.

The geometrical picture of space-time is an acceptable model for some areas of our experience. However, this does not forbid search for other representations, possible more adequate in a wider domain including numerous levels of scaling characterized each with its own velocity range. Unfortunately, modern scientists, blazed with the apparent success of relativistic theories, have entirely abandoned the attempts to fancy anything unusual beyond the relativistic cage. We blindly accept the Universe as a 3+1 (or N+1) dimensional manifold, and the very question about the special conditions and the limits of this coupling is an absolute taboo.

In general, any kind of dimensionality should be understood as a result of physical dynamics. Yes, various "theories of everything" include folding and unfolding of spatial dimensions at certain energetic boundaries (with energy intimately related to time). But such theories still admit an absolute "background" symmetry that can only be violated in many ways, but never transform into a different symmetry, or reveal a symmetry of an entirely different kind. The group theory formalism has subdued creative imagination, suggesting us the clones of the same theory instead of drastically new models. And, so far, nobody can tell why time gets stubbornly coupled to space still retaining an obviously privileged role. Even a child understands that, to make a box, one needs to somehow fasten its walls to each other; similarly, to build a 2-dimensional space, we need a "glue" to stick one dimension to another, and a different kind of "glue" is needed to bind time to space. Dynamic dimensionality has already found its place in nonlinear dynamics, albeit restricted to the geometry of flows in a "classical" space-time. What prevents us from considering space production in a manner we describe many-body quantum systems, using dimension creation or folding operators? Which, of course, is also a limited picture, admitting the existence of notions beyond our present comprehension (and yet never beyond any comprehension at all).

In the same manner, bluntly postulating the equivalence of the inertial and gravitational masses, we stop any questions about the origin of mass in general, and hence the possibility of different kinds of mass and the physical conditions required for relative (or local) equivalence. Formal elegance has eclipsed the physical sense.

In the same manner, demanding the stationarity of action in the variational formalism, we refuse to consider non-stationary systems (or higher levels of stationarity). The origin of the action principle goes back to simple equilibrium conditions practically important for medieval architecture. Newtonian dynamics could be derived from a quasi-equilibrium, introducing fictitious forces associated with the motion of the bodies (which is virtually justified by the diversity of the forms of energy and the possibility of their mutual transformation). However, such stationary dynamics is implicitly based on the presence of dynamical symmetries, and hence the famous Noether's theorem contains, in fact, a logical circularity.

One could readily collect many more dazzling ideas from all branches of physics. Do we really need such examples? This is the first principle of science: all we can is inventing models, and every model is only right within the limits of its applicability. For truly scientific rigor, every statement must be appended with a stipulation: “where appropriate”. We omit this phrase, just to avoid excessive wording. However, a lighter text is no excuse for a looser thought. A limited character of any formulation never goes away. The author should always mean it; the reader is to mentally restore the required reservations. Introducing a function, we refer to a particular domain and a definite range. Writing down an integral, we assume that integral formulation is acceptable in the object area of interest. Suggesting a symmetry group, we must clearly realize that any symmetry is approximate, and the results may be inapplicable in a less symmetric dynamic (on a different level of stationarity).

The laws of science are like legal laws: they tell us what is admissible, but they can never forbid anything. The law prescribes a proper conduct in the standard situations; but it is of no help in a real mess. Eventually, new laws summarize the precedents and establish a standard to cover a wider range of legal acts. But nature is the greatest criminal of all: there is no law it would not violate. So, take it with a funny bone. Dazzling ideas are no stupefying mystery; they are to sharpen our vision, and not to blind us.

Nonlinear Kinematics

The traditional Newtonian mechanics was a formal expression of the early human experience of motion, which was desperately sluggish by modern criteria, even in the common urban activities, far from relativistic speeds. Similarly, the experience of size and time grew from the compact things and finite events of everyday life, boldly extrapolated onto much longer distances and times. The vision of the physical world was largely anthropocentric, as people were primarily interested in what happened in the nearest neighborhood. Hence the essential linearity of the first quantitative estimates and the taste for extensive measures, piling up many little bits to get a big thing of the same kind. Everybody knew that, applying a ruler twice, we should get a distance twice as long, and turning a sandglass twice would mark the doubled waiting time. The first physical notion of space took it for an infinite sum of tiny rulers; the incommensurability of lengths that was quite a challenge for a formal mathematician did not much bother a physicist, as physical “points” could be rather large, remaining “infinitesimal” compared to the regular lengths of the model. Any differences within the typical experimental scatter could be realistically ignored. Similarly, a physicist may speak about infinitely small volumes in a gas, meaning that each volume still contains a huge number of molecules, to remain a thermodynamic system. Similarly, time was deemed to be a chain of elementary duration small enough to label physical events to the accuracy of the clock. In this “flat” physics, it was natural to characterize mechanical motion by the number of space units covered in a few units of time (velocity), and the total length of the path could be obtained as a sum of “infinitesimal” lengths spanned by the moving body in a single unit of time. Physical interactions (forces) might change the speed, but these changes still happened on a scale much below the accuracy of measurement and could be treated as independent of spatial displacement, pushed to yet lower level (which obviously puts an upper limit on the admissible speeds). The independence of the different levels of motion and the possibility of their superposition was yet another manifestation of the model’s linearity.

The power of this simple picture was the other side of its primary conceptual weakness: the observable behavior of the system was tied to the (physical) scale. For instance, a periodic process represented by a smooth curve will show up as chaotic motion on the time scale much courser than the process’ period; in some scales, the same process may look like a stationary state (a point, several points, or a spatial form, a body). The very consideration of different scales violates linearity, while any linearity at all is impossible without combining very different levels in the same theory. In this sense, binding time to space and considering curved space-time was a logical completion of that line. And a physical conclusion too, since relativistic time dilation and length contraction are bound to eventually violate the condition of the physical separation of the different levels in the linear model. The new physics is to investigate the virgin lands beyond the principle of superposition.

Just for illustration, let us keep within the smooth world of Newtonian mechanics, but admit that the transition from of spatial point to another is a little more complex than mere additive displacement. Traditionally, we write:

$$x(\tau) = x(0) + v\tau \, .$$

This expression unequivocally hints to the infinitesimality of spatial displacements due to the proper motion of the system as compared to the range of movements required to build the coordinate system (a frame of reference):

$$\langle v\tau \rangle << \langle x(0) \rangle \, .$$

That is, both velocity and time must be small enough. Trying to compensate long durations with very slow motion or, conversely, very high speeds with microscopic time, would mean yet another instance of level separation, and hence a retreat from physical uniformity. In some situations, this is a legal approach. Infinitely slow changes obviously corresponds to the usual adiabatic limit, while the opposite case of instantaneous transitions in an inner space drives us to a kind of quantum description. However, the both opposites imply an essentially nonlinear procedure of interfacing two levels of hierarchy with very different character of motion. This is normally achieved using a kind of statistics.

In the simplest case, one could add nonlinearity through an additional term quadratic in time:

$$x(\tau) = x(0) + v\tau + \xi(v)\tau^2 \, ,$$

which (for bounded v and ξ) seems to merely account for acceleration; but here, we mean a purely *kinematic* rule, and there is no physical force responsible for the effect. In some cases, this type of nonlinearity can be *locally* represented by an effective force; but this identification is in no way justified when it comes to the global structure of space-time. Thus, postulating the equivalence of a physical interaction and the spurious forces due to the non-inertial motion of the observer, we extrapolate a local observation onto the whole Universe, which is a logical fallacy. The above nonlinear displacement formula physically means that local geometry may change with time; for quick events, this effect is negligible, though it may become significant on the cosmological scale. Moreover, for a very long τ, the linear term is utterly unimportant:

$$x(\tau) = x(0) + \xi\tau^2 \, ,$$

which may also refer to the stationary systems ($v = 0$) exhibiting a kind of "cosmological" fluctuations. One could consider this addition law as the opposite to the usual diffusion formula, with the distance proportional to the square root of time.

Alternatively, one could admit the orthogonality of kinematics on the different levels of hierarchy:

$$x^2(\tau) = x^2(0) + q\tau^2 \, ,$$

which, in certain cases, could be approximated with

$$x(\tau) = \sqrt{x^2(0) + q\tau^2} = x(0)\sqrt{1 + q\tau^2 / x^2(0)} \sim x(0) + q\tau^2 / 2x(0) \, ,$$

thus returning to the same quadratic nonlinearity, with the only difference that the "cosmological" admixture depends on distance (which might be physically attractive). Of course, there are many more possibilities, neither of them being preferable from the formal viewpoint. Any choice comes from practical reasons. Still, the awareness of the very possibility of different kinematic frameworks is a remedy against mental stagnation and the exaggeration of the universal significance of the present state of our knowledge.

A Bright Thought of the Dark Matter

Humans are designed to hate any hindrances and seek for the ways to reach the unreachable. As soon as there is an impenetrable barrier, we get extremely curious of what could be found behind it, and our fantasy would readily compensate for temporary lack of evidence. Of course, we cannot fancy anything beyond the already experienced, and the true nature of “transcendental” things escapes vision, substituted for some anthropomorphic concoctions. Such naiveties serve the only purpose of instigation, a moral encouragement and a promise. Indeed, if we can at least think about what is hidden behind the wall, the wall is no longer entirely blind; even if there is nobody out there, we are free to populate it with the creatures of our own, starting with vague ideas and finishing with a regular industry.

So, given the Universe as a whole, our cosmological thought would instantly switch to the issue of multiple worlds, and the apparent consistence of our knowledge about ordinary matter would provoke claims of something not so ordinary yet to be discovered. Well, there are heaps of things we can see and play with; this does not makes us quite happy unless we dream up an impalpable mystery, some dark matter that cannot yet be grasped, thus giving us enough room to theorize and measure. Surprisingly, the majority of the world’s behavior is found to be due to that unknown substance, and the inquisitive humanity is imperatively obliged to bring light to that new and promising domain of experience.

For a philosopher this does not make any great surprise. The world is qualitatively infinite, and the same thing can be approached from quite different angles. Science means knowledge. Wisdom means the appreciation of how little we really know. It is always better to know; ignorance may be a disaster, but it is no shame. It is only stubborn adherence to the already learned and refusal to learn more that is to shun.

Today, when dark matter has become as banal in astrophysical discourse as big bang or black holes, and as experimentally justified, it may merely seem a matter of time for it to be eventually detected and included in the mathematics of the physical world. We are certain to soon invent an appropriate instrumentation to gloriously observe the truth of our conjectures. Meanwhile, everybody is free to guess what it all will really look like.

Well, why not? Probably, my personal preferences are far from the academic mainstream, but they could bring an innocent amusement to me, and probably to those who happen to read these lines before dark matter gets drawn out of the dark.

The majority of popular accounts picture dark matter as a special kind of matter interacting in a peculiar way, in addition to the already available fundamental particles and interactions as described by the standard model. However, when it comes to philosophical amusement, this approach does not inspire much enthusiasm, since mere discovery of yet another physical force is too dull, too habitual nowadays. I don’t mean that there is nothing to add to the standard model; moreover, it is bound to expand in that way or another. It is quite admissible that some kinds of dark matter could fit in that extensive line. But I am as sure that our old acquaintances may sometimes show up in unexpected turns, as the observation point shifts a little bit away. The standard model is humanity-centered; it is perfect to speak of the world as we see it here and now, but it may, too, be useful to look at ourselves with somebody else’s eyes, to give life an intensive coloring.

For instance, let us meditate over the possible effects of relative motion of material bodies. Please don’t tell me that the issue has long since been exhausted in this era of ubiquitous relativism. Going without saying for many decades has nothing to do with standing to reason. One might reason that the outcome of our efforts to construct a covariant Universe does not well agree with its underlying ideas, and primarily, with the idea of a frame of reference. First, we admit that an observer may have a universal scale for the whole space-time; later, we find that some portions of space-time are utterly inaccessible to the observer, whose observations can never go beyond the light cone. An inherent logical fallacy is obvious. However successful in applications, such a theory can hardly be taken for serious as a model of the entire Universe.

As it often happens, the humanity grew accustomed to relativistic physics, and people just don’t care to grasp the meaning of their own words. Even forgetting for a while, that any formal singularity can only be an indication of conceptual insufficiency and the necessity of a more elaborate model, one should be more attentive to the consequences of the commonly adopted theory (quite useful within the limits of its applicability). Indeed, all Einsteinian relativity tells us is that, as long as we use light for a communication standard, there is no way to compare the observations of two observers moving relative to each other faster than light. Isn't it obvious from the very beginning? Of course, such observers will have to seek for a different information carrier, to get in touch. However, this does not prohibit neither the possibility of such relative motion, nor the ability of physical interaction. Thus, two observers may exchange light signals with each other, as their relative velocity is low enough, but the both will remain invisible for a third observer, for whom they move too fast; this latter may find companions within the same light cone, who would be as incapable of communicating with the above faster-than-light couple. In this model, the whole space-time acquires a kind of cellular (or lattice) topology, with the creatures within each cell believing that their limited world is all that mother nature can afford, just like modern physicists do.

Here comes dark matter. There is an infinity of relativistically separated worlds, so that, for light-cone prisoners, the bulk of dark matter will always be overwhelmingly bigger than all the visible matter of their single-cell world. Some dare to estimate the quantity of dark matter in up to 99% of the mass of the Universe; in view of the out-there infinity, they are not brave enough.

So what? Are we doomed to eternal solitude, with no hope to talk to our faster (or slower) colleagues? Not at all. Within its light cone, faster-than-light (dark) matter is just ordinary matter, and the same standard model could explain its structure and interactions in exactly the same manner. Being of essentially the same nature, material bodies of different relativistic cells can interact with each other, and all we have to do is to guess how a faster-than-light electron should behave in the presence of a slow electron (and the same for the other inhabitants of the standard model). It may well happen, that some of the intruders would take the guise of the ordinary particles and fields; some others may look like apparent singularities or, at least, apparently causeless events, like spontaneous symmetry violation or certain phase transitions. There is no reason for nature to stick to the only possibility.

Just for illustration, consider a very fast material body moving in a limited volume. Viewed by an earthly observer, it will seem to fill the whole volume as a kind of field. Inner (faster-than-light) motion is perfectly hidden, and all we get is an overall effect of virtual interactions upon our "macroscopic" world, a kind of spectrum. The well-known quantum paradigm. The brethren-physicists may sit within an electron, and, to communicate with us, they will need to work hard modifying its outer behavior to the extent that we could not ascribe it to mere physical force. In our world, similar activity might look like rearranging matter on a scale comparable to the whole visible Universe.

But let's be optimistic and seek for universal signal carriers other than light, to make relativistic barriers transparent. This would allow cross-barrier interactions and the existence of material bodies combining the phenomena of many levels. Still, I admit that the hierarchical organization of nature in general (and the physical nature in particular) is not much of a news.

On Inertial Rotation

Starting from Galileo, we are strongly convinced: while no outer forces act upon a physical body, it will steadily move along a straight line. Consequently, two observers moving one relative to another with a constant velocity will deal with the same structure of forces in any physical system.

Later on, a couple of scientific revolutions has attached forces to fields and connectivities on manifolds, for uniform linearity to give way to geodesic displacements. This, however, does not really change anything, since the whole theory stands on the same notion of a locally plain space (regardless of how we formally marry it with time).

Well, but what if space is not indeed that plain? Even locally. Or, maybe, it is plain, but not in an entirely traditional sense?

A modern physicist, who has long since got accustomed to mathematical indiscretion, would hardly ever object to the very formulation of the question: all right, let it be non-plain; then, what is it like? In the toy theories of everything, there are tons of topological perversions; should anybody seek for more? Well, in the quantitative sense, that's enough; but there is always way to dig a little bit deeper.

I admit that an outlook of a nontrivial philosophy is far from making the scientists of today entirely happy. Still, the problem is essentially philosophical, as we have to decide on primality. Which, of course, is relative, but never to the degree of utter disappearance in any particular case. Now, our question in the philosophical language looks like that: what can be considered as primary to inertial motion in the traditional sense? It seems like there is nothing else to lift from a completely free thing, which is simply allowed to do as it likes, flying on, just following its nose… At this point, a politically mature person will yield to vague suspicions, since there is no freedom on itself, we can only be free *of* something and *for* something. It is in the tall tales of the bourgeois propaganda that the ideas of absolute and unrestricted freedom get spread like butter on bread, regardless of epoch and range; their "universal" values eventually turn out to be the values of a bourgeois, and their "common" liberty becomes the "natural" right of a capitalist to plunder all around and, with all kinds of arms, cut short any attempt to take a bite of his sacrosanct property. Similarly, the talks of free motion in physics might well disguise the same bourgeois absolutes; in this context, the delivery of Galilean mechanics at the very dawn of European capitalism is in no way a coincidence. Never mind, this was a lyrical digression for the most inquisitive; from the physical consideration, we only spare ourselves the right of doubting the very presence of independent and non-interacting bodies, and hence the workability of the classical inertial motion.

Indeed, how should we learn about an absolutely free body? It does not know anybody, and nobody can see it. It's of no use for anything. In other worlds, it does not exist at all. Or, even if we grant it a kind of existence, this would put it outside the physical realm, as yet another immaterial abstraction. Keeping off religious savageries, such (ideal) formations are nothing but the features of things and their relations, rather than things as such; it is in this sense that we speak of their secondary (or derivative) character. Surely, any contrast is relative, and we always need a definite context, to distinguish the levels of hierarchy. This, however, does not remove the presence of hierarchical order in any specific situation.

One can only speak about motion (for instance, mechanical) in respect to something taken (in the current context) for immobile. What stands behind such a relatedness? In classical mechanics, the observer almighty arbitrarily connects and reconnects things, to produce a common frame of reference. This is an instance of the same abstract totality, since philosophy adopts the universal connectability of all things as a most general definition of the conscious subject. Now, if we (as appropriate for natural sciences) exclude the observer, all what is left is interaction, the influence of one body onto another. The outer distinction of the bodies must affect their inner state. In certain cases, and in certain respects, the state of one of the interacting bodies would vary less than the state of the other bodies, so that this relatively stable physical system could objectively play the role of a frame of reference. The traces of interaction with many other bodies mutually interfere within such a (material) reference system to allow the common presence of several bodies in one. Just rescind this amalgamation, and there will no longer be any interconnection, with the physical system splitting into a number of independent systems.

Classical education still suggests a one-way bias: there is a frame of reference, and there are physical bodies moving in that frame. Even admitting a shift to another observation point, we yet fancy the same overall construction in a different observer. When a physicist speaks of a transition to the frame of reference associated with one of the moving bodies, this is a metaphor, a sort of useful trickery; logically, a frame of reference can never be attached to any of the bodies represented within it, since this is a higher-level construct, a stable system of bodies. Nevertheless, since the very representedness in a frame of reference means interaction, one can never entirely rule out the influence of the frame on the motion of the bodies it embraces, which also assumes the indirect interaction of the physical bodies through the common frame of reference. Sometimes, this will count to a negligible correction; the bulk of classical physics piles up in this way. In other cases, conversely, a frame of reference would actively shape the physical system, imposing a specific mode of motion that does not pertain to the bodies "as such", that is, the same bodies taken in a different respect. This holds for quantum correlations; similarly, the society makes the human brain serve a culturally determined activity, though, on itself, this piece of flesh is devoid of any sublime inspiration, it does not assume any consciousness at all.

Well, suspending the primacy of uniform rectilinear motion, where should we look for a new conceptual basis? Let's approach it from a different direction. For instance, I (as a frame of reference) sit in the same place and do not move; but I can disturb the outer world in many ways (say, emitting some probing bodies, outgoing signals) to register its reaction (incoming signals). Admitting that my signals travel with the same speed in any direction (and what else could I assume in my stationary world?), I evaluate the positions and velocities of any physical bodies. Note that the detection of an incoming signal does mean anything on itself; any unauthorized intrusion is normally treated as environmental or instrumental noise, which many generations of physicists tried hard to eliminate, all through the history of science. Only those signals are considered as informative that come in response to our exploratory actions (though this parentage can sometimes be extremely distant, highly indirect, up to the illusion of "pure", unconditioned contemplation). That is, our notions of physical motion are based on the "inquiry–response" scheme; in philosophy, we call it a "reflexive act" (often, simply "reflection"), with a thing as if going out of itself and coming back. Reflection is in no way a god's gift; it can be found in a smallest portion of the Universe, and equally, in the Universe as a whole. What goes around comes around. Just turn around to turn up. All the parts of the world participate in universal reflection on different levels; with any particular part, it looks like regular recurrence, self-reproduction of a (relatively) durable integrity.

All we have to do is to express the same in the language of a physical theory. No good news for the adepts of static knowledge, for those engaged in erecting the only true depiction of the world, valid for all times. The same can differently manifest itself in many possible circumstances, and no formal model can grasp this versatility in full. There are no theories of everything; such constructs are beyond science. However, each level of research will coin abstractions representing the universal ability of reflection in a "natural" manner. Periodic motion in general (and harmonic oscillator in particular) are, probably, the most common examples. As soon as we pass to additional spatial dimensions, we can picture it as rotation.

In everyday life, we find that any motion at all is somehow related to rotation. The relocation of business freights and laboratory objects gets detected by the changing angles of observation; all that is pinned to a spinning planet involved in periodic movements of many a scale, including, at least, orbiting the Sun and following in its rotation around the center of the Galaxy. In fact, the very existence of compact cosmic objects assumes some limits for the relative motion of its components, which means oscillatory change of their positions and velocities within a final volume. Even considering collective states typical, say, of the inside of a neutron star, we do not avoid the issue of the oscillatory modes of motion that determine the possibility and spectrum of the observable radiation. Angular momentum conservation law is no worse than momentum conservation, while rotation exchange is as common in space as redistribution of translational velocities.

A logical conjecture: it is rotation that should be taken as the most general and fundamental form of motion, while infinitely straight lines are nothing but illusion arising from our usual experience limited to almost zero angles and relatively long radii, with the corresponding arc paths (linear displacements) significantly surpass the characteristic size of the observer. The exploration of the outer space has demanded a revision of our notions and freed us of many illusions; however, the idea of the primacy of rectilinear motion has proved to be stronger than the idea of the privileged role of the Earth (or the Sun) in the Universe: the primordial anthropocentrism is more deep-rooted than geocentrism. Our body is our first scale, the level of hierarchy to start any unfolding. We need much more time to inwardly accept the possibility of other scales.

In respect to rotation, the principle of inertia takes a slightly different form: in the absence of any outer influences, any rotation will proceed at the same rate for all times. This does not entirely match the classical conservation laws derived from the fundamental role of spatial translation. When a mass goes round on a circle, its angular momentum is preserved; however, classical inertial motion along a straight line will also conserve angular momentum, with the rotation speed slowing down at farther distances from the origin. In the world of inertial rotation, this trick won't work, as we demand the constancy of rotation rate regardless of the radius. This new vision of inertia implies that no "free" body can infinitely go along a straight line, as its trajectory will necessarily “curl”. Linearity is still kept as a local approximation valid for short tracks far away from the rotation center, the origin of the corresponding reference frame.

At this stage, the formal applicability of traditional theories is in no way restricted. All we need is to admit that there is no plain space-time, or, in other words, that gravity is the fundamental mechanism of reference frame formation. Nobody’s going to contest that. Moreover, we don’t necessarily need any point masses, which are not just physically real. On the other hand, we have long since grown accustomed to all kinds of “inner” motion in quantum systems. For a banal example of a self-supporting rotation, take the spin of microscopic particles usually pictured as rotation in some special space, where we do not know any physical forces that could act inside such spaces and make them anisotropic; it is not utterly impossible that some interesting discoveries wait for us in this line of thought.

Technically, mathematical physics makes use of two complementary concepts: power expansions and trigonometric series. Both are practically useful. The same function can be represented either by a power series or by Fourier integral. Still, the theoretical load of these formally equivalent representations is not the same. Power expansions lie in the basis of dynamic description, while the Fourier transform is mostly considered as an auxiliary, a matter of convenience. What if we reverse the roles? Why not picture the Universe as a hierarchy of all possible rotations (oscillations), considering a change in the state of rotation fundamentally important, primary to mere displacement?

It is not evident, whether such a viewpoint could be of any practical use. Power expansions are built in our everyday life; they incorporate the idea of stage-by-stage advancement, transition from one goal to another. Reflexivity is thus represented in its most folded form: we mark every return to the origin, but we do not care for anything in between, in the “dead” time. After all, any positional numeration system is all power series; yes, we know that there are other cultures differently structuring quantity, but we treat such notation as something rude and primitive, as temporary aids that are only valuable until we come to the “true” science of numeration. Quite probably, numeration systems based on Fourier expansions are as interesting, but they alien to our habits. Except, possibly, a few very special areas (for example, music). From philosophical considerations, however, one would deny any absolute “primacy”. The inhabitants of some worlds will find rotation more natural; some other cultures will produce a counterpart of our “perturbation series” approach. One is also certain to encounter situations where neither of the two properly reflects the structure of activity, and we’ll need deeply original inventions (though one might meet the old acquaintances somewhere behind the curtain).

In the era of the triumph of the Standard Model and intricate cosmologies, the appellations to the ages-old common intuition may seem utterly improper, if not obscene. A physical theoretician would possess an intuition of a higher rank capable of operating with abstract combinations of abstractions. And this is right, as it helps the humanity to tramp on to the bright future filled with advanced science and technologies. The practical importance is above all.

The souls of less concrete and quarks may sometimes grow vaguely suspicious: isn’t the world too prompt in yielding to our prescriptions of the truth? Once we have postulated the constancy of the speed of light, we get tons of positive evidence at every corner. We have built an impressive theory of all the fundamental interactions, and voilà, all the particles we could predict. Just draw a couple of universal inequalities, and stage an immediate experimental justification. Black holes, gravitational waves… Anything you like. Just wish and get.

No doubt, our discoveries refer to some real portions of nature, and our smart theories can perfectly cope with that splendor. Still, inebriation with success is no better than any other drag addiction. Nature can never be reduced to what we have already found and mastered. Who can tell in which part our achievements are due to the merits of the method, and what is rather a (practically important) artefact? The Universe does not offer us more than we are able to ask for. See above, about the frames of reference. So, we roll on and on by the circles of cultural inertia, and we cannot drop out without an outer force. Maybe. But its inevitable intervention may yet be not so far away.

Heads Properly Placed

If hands were feet, ’t would be in vain
to have the head still host the brain.
Meraïlih

Every normal person intuitively grasps the essential difference of time from the space. We cannot clearly explain the feeling, we just need them to differ, to prevent our life from turning into a sheer mess, with no order at all. It takes a really dogged theoretician, far from the need of earning the daily bread by digging the ditch from here to then, to keep on with the frivolous geometrical play in some perpetual god-made scenery. Still, even the enlightened ones occasionally have to pace something out and consult the watch.

Just here, we say “Hold hard!”, suggesting to drop a couple of thoughts to the physical sense. Which, as every (normal) physicist perfectly knows, is determined by the way we measure the physical characteristics; this is exactly what we treat as their (practical) definition. One could proceed with comparing different technologies to each other and spot the possibilities of substituting one for another. For instance, having no nails, or no hammer to drive then in, or just facing a damn-concrete surface, we still have the option of using an assembly adhesive, so that the mirror would keep the proper position anyway. Alright, we happen to drop in a bar without an alcohol meter; nothing disastrous, we still can estimate the overall hardness of the drinks by the percentage of the passed out. Similarly, the physical laws connect certain values to each other, which allows us to judge about something we cannot (or do not want to) directly reach.

Blunt logic concludes, that, to distinguish this from that, we only need to compare the modes of practical treatment… Sheer miss. In many cases things exhibit just no apparent differences. In Ancient Greece, this circumstance gave rise to quite an industry of coiners; fortunately, some Archimedes could dive deep in the essence of things, and managed to flush the dirty tricks off. In the same way, to take temperature for something different from the length of a liquid column (or the volume of a solid body), one needs a real piece of work: first invent analytical mechanics and thermodynamics, spice them up with classical and quantum kinetics, and it is only within that hierarchy of sciences that temperature could be treated as an essential parameter of the theory irreducible to anything else. Of course, no warranty that some smart engineer would not, one day, bring about a gadget from far beyond the nice theories, which would drive us to dumping our comfortable notions in a dusty corner to get more room for a newer conceptualization.

Why, isn’t it what Mr. Einstein and a whole lot of the later promoters of relativism, on all the levels of vulgarity, keep telling us for a century, or so? That is, the intuitively felt distinction of time from space is nothing but spurious, while reality (whatever is meant) would never care, and there is no time, and no space, but solely a four-dimensional geometry with a proper signature. Consequently, things never move (god forbid!), but rather stand (or hangs?) transfixed (by whom?) like a huge piece of abstract art. However hard we try, we can nothing change in this ideal geometrical world; well, and there is no longer any need to… Some people (namely, the money-bags) would certainly find that flavor of science really handy!

To speak of fundamental differences, blunt logic is not enough. We have to engage much stronger abstractions, so to say, abstracting from the very abstractness. Thus, instead of a plain scientific theory, we’ll get a general principle, a guiding idea. Which is most helpful in revealing the true ideological face of anybody, and hence follow the line of Archimedes as to ruling the tricksters out. For instance, the advocates of the bourgeois principle of social equality are never really favor the attempts to compare them with any rabble, cutting short any encroachment on their personal and real estates, access to the pork, or their bank accounts. Similarly, just try to explain a high-ranked physicist that he does not really understand what he does, and, the next moment, the scientific community will spare science your further presence. A professional does not need to talk to dabblers, as the laymen are not permitted in the refined world of self-contained professionalism.

The dictate of geometry is epidemically ubiquitous. Well, it may be a kind of fun, to watch a philosopher who, just to share his intimate vision of the spatiality and temporality with the world, has to waste dozens of tedious pages taking an oath of absolute love for Einstein and indignantly denying any suspect in plotting against the foundations of modern physics. In the modern fashion, physics runs the show, and any philosophy must make friends with physics, consult it for each trifle issue and ask for the royal permission at every turn. This may closely resemble the similar apologies to Aristotle or the Pope, about a thousand years ago.

Still, let us dare to part two classes of measurements that cannot be reduced to each other, so that their common basis is to be sought for in something much more sublime.

Roughly, there are things we can observe together as co-existing within the same activity; however, there also exist "incompatible" things that can only show up one by one, as the appearance of one means the disappearance of another. In the former case, a thing is given immediately and at once, so to say, in the same time, and in the entirety of its "spatial" scope. The latter case assumes a mere sequence of simultaneities, and we just guess about the whole from these snapshots, ideally establishing their commonality within yet another integrity, "time".

Of course, we often express parallelism through sequencing, and the other way round. Does that remove their principal difference? Not at all. It may only change its form, flow from one level to another. Thus, space is readily represented by the time of some "standard" motion. However, you still need to simultaneously consider the starting point and the result of the motion as belonging to the same thing (space); otherwise, there will be nothing to express. Attaching some "unit length" segment to a spatial thing several times, we are to (mentally) retain the whole sequence of applications, counting them. When it comes to the distances much greater than the size of the unit, we run off the count, losing the original motivation, and all we get is the process of measurement as it is, pure time. Conversely, any spatial representation of time by the spatial range of some standard process (like the wavelength stands for the oscillation period) means that we can distinguish the starting point from the destination: that is, mere phase picture, or a standing wave, is not enough; we have to reconstruct the process of *propagation*, shifting the position of the same phase.

In the popular literature, they like drawing the diagrams of motion, setting up one axis (say, horizontal) for space and another one (vertical) for time. Isn't it a perfect static vision, in a complete agreement with the idea of geometrical time? Well. Just draw there a circle. Is it a mere geometrical figure or a process? What, in one context, is but a diffraction picture may well come out in another as a working cycle of a thermodynamic machine. The feeble objection that, in a diagram of spatial motion, no curve cannot be closed (since time does not go back) dies at the spot: first, some physical object just like turning time back (*e.g.* positrons); second, if an unclosed curve is to represent a process, we still need to specify the order of its points, thus mentally adding time to sheer geometry. Moreover, in real life, most different scale may apply to the same. For instance, let a point oscillate with a constant period; the graphically, we get a sine curve along the time axis (say, left-to-right). Now, switch to a scale with unit much greater than the oscillation period. What will you see? A horizontal band. Is that virtual up-and-down motion of a point, or is it a stationary state of a continuum of points (a segment of a line)? Why not take that for a reason to identify the two physical systems that are indistinguishable in this scale (though they may well get apart on a different level)?

Let us come back to the procedures. We measure space comparing one length with another; this implies a (virtual) displacement along the measured thing, as well as counting the number of the steps (the total time). Conversely, to measure time we stick to the same point and run a clock, which would (hopefully) march with the same pace; however, we need to somehow distinguish a "tick" from a "tock", and the only way to do that is to attach spatial markers: a clock hand jumps from one mark on the dial plate to another, the sand runs from the upper compartment to the lower, and so on. The fancy electronics does not really change it, as it only serves to visualize spatial distinctions (take the proof for a home exercise if you wish).

Rescaling time, we risk to run into a resonance, effectively eliminating time, with the clock hand stuck to the same grade. Similarly, spatial measurement can produce the impression of no progress: we apply the ruler time after time without no visible change. This is what we call symmetry. Should that cause any real problem? Just take another ruler and a different clock, and everything will wake up and run on. Unfortunately, life would not always leave us much choice, and even what we have may be far from what we need. No, it is not just mean. There is a very solid reason that we call hierarchy.

The difference of space and time is related to the organization of the world in general; for humans, it is primarily revealed in the forms of human activity. Hierarchy is a way of universally connecting things to each other, so that a push to some element is bound to influence all the other elements, though this influence is never immediate, but rather propagates from one element to another in a definite order, which is called hierarchical structure: the elements of the same level respond “simultaneously”, they belong to the same “space”. What if we push a different element? Well, a different wave of responses will propagate through the whole, and this new ordering will show a sequence of level of its own. That is, the same hierarchy unfolds into many hierarchical structures (the *positions* of hierarchy). Obviously, one does not need to resort to brute force; thus, developing a theory of that hierarchy, we can vary the basic notions, with the corresponding change in the structure of the theory.

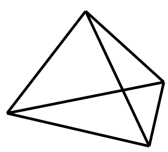
Of course, this does not exhaust all we know about hierarchies; still, the overall idea is clear enough to bring more light to the nature of (physical) space and time. Here, it is important that a hierarchy cannot be observed but through one of the possible unfoldings. A mathematician would prematurely identify a hierarchy with the set of the possible hierarchical structures; but this is wrong, since a hierarchy can also be treated as many hierarchical systems, and besides, there is a history of the hierarchy’s growth, which adds a specifically hierarchical aspect.

All the positions of a hierarchy are equally valid (since they represent the same in different ways); this is the core of relativity principle. However the equivalence is also relative, referring to a specific level of the hierarchy of hierarchical conversion; in a wider context, the paradigms will mutate.

Human activity looks like a sequence of actions, so that every action is to start with something certain and to produce a specific result, thus spanning a definite volume of the “cultural space” (psychologically represented as a motivation space). The beginning and the end of an action are fixed, with something very diffuse in between, which implements the very process of transition. In respect to its actions, an activity is a higher level of hierarchy: we can indicate the previous and subsequent actions for every particular action, but the whole activity does not imply a beginning, nor end, being an abstraction of succession, pure time. For each action, we have just enough time to construct its inner space; all the rest is beyond it, at “infinity”.

However, what serves as a higher level (activity) in respect to an action will also play the role of an action in a more global context. Looking to an action from above, from the level of an envelope action, we can no longer discern the starting point and the end, they merge into a single entity, entirely hiding the details of the transition. Thus an action folds into an operation: a point, an instant. This does not remove the inner complexity, and we can unfold an operation into a full-fledged action whenever needed. An operation is infinitesimal; but it does not equal zero, sheer nothing. The problems of formal theories mainly arise from too literal approach to a point (an instant) as an entirely unstructured abstract indivisibility, utterly impenetrable. Mathematically, this leads to all kinds of singularity.

Now, the distinction of space and time is related to unfolding a specific hierarchical structure; in a different position we’ll get a different picture, which may look like a mixture of space and time : in the new space one find a portion of both former space and former time, while new time gets formally represented with a combination of the old-cut space and time. Why? Just because the formal approach flattens the hierarchy, removing the distinction of its levels in a savage manner, just identifying one with another. For example, consider a conventional picture of 3-dimensional body (tetrahedron) in the plane:



Most people would easily grasp the idea and mentally add the missing dimension, putting the vertex corners at different levels. From the formal viewpoint, all the nodes and links lie in the same plane, and there is no reason to prefer one order to another. Similarly, some “physicists” do not distinguish space from time, since their formulas treat them on the same footing. True physics would never confuse the ways of expression with natural phenomena; to get to a meaningful result we have to somehow introduce physical time, even at the price of neglecting a bit of mathematical “rigor”.

Alright, but why the all-embracing geometrization still happens to properly work? Because the positions of a hierarchy, in their turn, form a hierarchy, which may (and must) be unfolded in all the directions. In particular, in some hierarchical structures, the distinction of space from time is of little importance; it goes to the lower levels of hierarchy and we can dismiss it, to a certain extent, within a particular approximation. On the other hand, as long as we employ the traditional means and methods of measurement, there is no need in a more profound theory. Still, if, some day, we manage to implement transition between the reference frames moving in respect to each other faster than light, our models of space and time will have to take a more appropriate form.

Every act of measurement compares one thing with another, mentally (or practically) dividing the whole to portions that we deem to be equal (by definition). The latter condition is not as easy to satisfy in real life: thus, evaluating distances by the number of steps (or any other “physiological” measure like feet, inches or furlongs), we have to admit a certain degree of variability in the unit size during the very process of measuring; still, this minor circumstance may make no practical difference (never influencing our decisions), and we can boldly promise to account for it in the next approximation (if ever). However careful our choice of the units might seem, their constancy is an entirely practical issue, and nobody can guarantee that the “fundamental” constants (including mathematical ones) would never start to drift. Nevertheless, there is the same basic commensurability of a physical parameter and its unit, as any quantity can only sprout from a definite (and hence relatively stable) quality. Can we immediately measure distances with a clock? No, we first need to somehow convert the clock readout into spatial units, or the other way round. There is a traditional trick, multiplying time by a dimensional constant, the speed of light. Insofar, the fundamental nature of that speed (and its constancy across all the reference frames) is to be directly postulated, just on the grounds of that, with the present technologies, there is no other choice. That is, the speed of light is certainly constant because we evaluate velocities in the unit of that very speed, no alternative in stock.

Similarly, one can express time in terms of distance as long as there is a practical procedure converting one into another. That is, the geometrically posed physics will work within the areas of such (at least plausible) feasibility. Exactly the same could be said about the measurement of intensive characteristics, like electric current or temperature: where the available technologies allow associating one feature with another, the physical theory is free to exploit such conceptual links.

How is that reflected in the organization of human activity? Well, if you can split an action into several actions *of the same kind,* this will produce a quantitative estimate. For example, to march from point 1 to point 4 in three steps, we first go to point 2, then to point 3, and yet another step will fetch us to point 4. In a different scale, we can might need 10 or 1000 steps; this does not change the overall procedure of repeating the same operation time after time, always remaining on the way to the destination point. The possibility of such a sequential transition from the starting point to the end is related to *continuity*.

On the contrary, when an action gets unfolded into a combination of qualitatively different operations, no quantitative estimate is assumed. Thus, one could directly go to point 3, and get to point 4 in one more step; however, the two operations are incomparable, as we are not sure to reduce the first leap to sequential unit steps (just admit that point 2 is physically inaccessible, or forbidden by some “selection rules”). In some situations, one may need to first jump up to point 5, and then step back to point 4. This is the principle of laser construction. Thus structured activity is called *discrete*. Note that the “unit” operations do not need to be equal in any physical sense: in the C-major scale (and other musical modes), the intervals between the adjacent notes differ, still referring to the *neighboring* grades of the scale.

In general, any activity unfolds into a diversity of operations, which are only compatible in being arranged for the same purpose. To build a house, one is to dig a foundation pit, lead in the service lines, lay the foundation, mount the walls and floors, and so on, up to outside and inside finishing. In some cases, we could find a common measure even here: thus, if we are not specifically interested in the house but rather in the overall construction time, any operation will lose its individual quality and become a sheer duration. Similarly, the market transforms qualitatively different articles into abstract values that can be exchanged in any combinations. Recalling that, in K. Marx' economic theory, the value is nothing but a quantitative expression of the socially necessary production time, we can conjecture that any quantity at all is primarily related to time, while the qualitative distinctions are akin to the spatial organization. In particular, natural numbers sum up a specific activity, enumeration (counting), which puts some objects in a definite order, thus making than sequential time marks. In this context, it is clear why physical "theories of everything" mainly add spatial dimensions (including any inner spaces), while the one-dimensional nature of time is always preserved.

Let us look closer at the construction of the clock. A physically perceptible thing necessarily has a definite quality, and hence it is spatially organized. This means, in particular, that we can compare different things, taking then all together, at once, "now". Thus, whenever mechanics is to characterize the position of a material point by a coordinate x, this implies comparison with some reference point, the origin of the coordinate system. It is important that the two points are intentionally treated as *different*: if they happened to be the instances of the same point, their distinction would be quantitative, as of the stages of motion, and one would have to seek for some qualitative characteristics to be able to speak about material points as such. That is, the very possibility of geometrical representation (including the construction of the frame of reference) implies *instant* (at the current level of hierarchy) transition from one point to another, and back. In the common terms, we just look at one thing, then look at another, and then tell how they differ. If so, whence the idea of a speed limit?

To produce an impression of motion the same thing must be taken in different respects. Is it, in real life, that we need to do several things in a time? Every now and then. However, a direct comparison of the different aspects of a thing will just add one more spatial dimension, producing the same static picture. Playing as much notes as you wish together, you make yet another (albeit utterly dissonant) chord, which is normally perceived as a peculiar timbre of a single note rather than a melody, a succession of notes; yes, cool professionals can mentally decompose a chord into melodic movements, but the formation of such an ability takes years of training, tuning one's perception to a definite musical system. In other words, to get the "time coordinate", we need something very special, which is not comparable to the rest of the system's parameters and hence cannot be placed in the configuration space. This odd thing (or activity) must be unrelated to the original activity; thus we return once again to the idea of hierarchy.

So, where is it, time? Let us recall the simple fact that a description of a thing does not coincide with that very thing; a name is unlike what it names; a formula merely represents a physical law, having nothing to do with the physics thus meant. Sometimes, one can take a thing's image in a mirror for a real thing, but we perfectly know that such deceptions are transitory, as any illusion. Just try to pay attention to what you do, and you'll stop doing it, switching to a quite different activity, known as reflection. Returning to the prototype activity (enriched with the experience of self-observation) requires a special effort.

That is, in the mechanics of a material point, the activities of two different levels meet: first, the determination ("measurement") of the current state of the system (formally represented by the spatial coordinates), and second, repeated distraction to yet another activity, comparing the results of different measurements (and hence a kind of self-reflection); the latter (within its proper level) is much like comparing the points of the configuration space, which may lead to a formal similarity, an illusion of time coordinate.

Obviously, the separation of the levels of physical motion and its reflection is only possible under rather strict conditions. Any measurement in the configuration space is assumed to be practically instant, entirely kept within a single act. On the other hand, the cycle of reflection should not interfere with any inner symmetries, the characteristic times of inner motion; otherwise, we could either miss motion, or find there inappropriate (artefact) structures. In a very simple case, one measurement immediately follows another, so that the system's state is not likely to significantly change in between. The opposite limit of very scarce measurements will produce an impression of random motion, possibly obeying a definite statistics. When the motion of the system cannot be separated from the acts of measurement, we speak about "quantum interference", or, at least, a combination of quantum and classical traits.

Of course, the anthropomorphic slang is not to be mystically interpreted: the same physics is produced in the interactions of natural things, without any human snooping, so that one thing becomes a mirror for another, or the other way round, depending on the character of interaction. People are certain to intrude with the nature's affairs; they are bound to adapt things to human needs. However, nobody can impose anything to nature that would not comply with its inner predispositions; we only use what we can get.

Provided the reflection cycle is very short (while remaining much longer than the characteristic time of measurement), another mechanical system of the same type (a material point moving in a space) can serve as a clock. In this case, time labels for the acts of measurements will compare the positions of two points in their corresponding spaces. Thus time takes on even more spatial look, prompting us to boldly draw diagrams with the position of the point of interest on one axis (say, X) and the position of the reference point on the other axis (space Y). In particular, a photon could be taken for the "clock hand", to get the dimension of time dividing the photon's coordinate by the speed of light. Similarly, in two-dimensional configuration space, we can, under certain conditions, establish a correspondence between the displacements along the two orthogonal axes (or, alternatively, the radial motion and rotation). However, doing that, we compare the motion of two entirely different systems, or the incompatible aspects of motion of the same system. Such pictures (and the corresponding formal "spaces") are called phase diagrams; they are very unlike configuration spaces, where physical motion is to proceed. The geometry of phase spaces has nothing to do with the geometry of the physical space, since it essentially depends, in addition to the methods of determining the state of the system, on its dynamics and the modes of observation. On the same grounds one might take the momentum p of the particle in the point x for a phase coordinate, obtaining a phase diagram of the well-known type as an alternative representation of the system's motion. The (x, t) and (x, p) diagrams are dynamically interrelated, and they may even look alike. For the motion with a constant speed, we get a straight line on both diagrams, though this line will be parallel to the X axis in the (x, p) space. For a constantly accelerated particle with a constant mass, the (x, p) diagram will exhibit a straight line slanted in respect to the axis X, while the (x, t) space will seem "distorted".

In general, the state of a physical system is a hierarchical structure, the way of unfolding a hierarchy. Any transition to another state (provided the integrity of the system is preserved) assumes folding one structure and unfolding another, that is, hierarchical conversion. Physical motion is mainly an example of such conversion, a cycle of folding and unfolding. That repetition serves as a natural, or "inherent" clock for physical time. Of course, time is hierarchical as well, and one find very different "characteristic times" on the levels of that hierarchy. It is only in certain approximations that we can reduce time to a single number, a time coordinate. To absolutize the odd cases like that is far from the true method of physics, since the artificial character of such a formalization will manifest itself sooner or later, requiring a separate consideration of the effects of different scale.

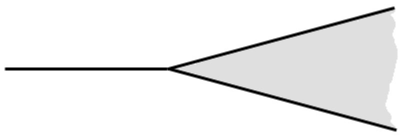
Equilibrium in Manifolds

General relativity theory is indeed one of the greatest breakthroughs in human reflection. Despite all its inherent fallacies, it gave us an entirely new perspective: nonlinearity. While the preceding centuries favored a linear, or at least linearized, picture of motion, admitting nonlinear effects as minor corrections or a statistical artefact, general relativity postulates nonlinear equations of motion, and there is no way to eliminate this principal self-reference from the physical science. A few decades later, nonlinear fields have become commonplace in fundamental theories, and the very kinematic layout is now to include all kinds of structural rearrangement.

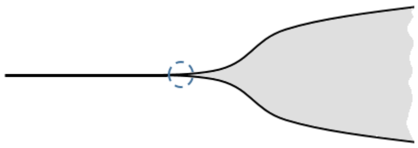
With all that, the emancipation of nonlinearity lacks ideological guidance, hence looking quite arbitrary; no wonder that the most attractive results of nonlinear dynamics are mainly related to (quasi)stochastic behavior and chaos. Still, this brings yet another important premise: the geometry of physical motion does not need to follow the geometry of the underlying equations of motion; that is, the global structure of the ensemble of "world lines" is not necessarily a space (characterized with its overall dimensionality and topology), but rather a manifold "embedded" in a space structured according to the specific nature of the interactions involved. The next logical step is to limit the ubiquity of physics, allowing for changes in the equations of motion in the course of motion. In this way, two observers may also differ in their attitude to dynamical laws, and not merely the way of their parametrization, which demands yet another generalization of the notion of a frame of reference. In other words, there is no "embedding space" at all, and all we have is a physical manifold, with dynamically changing geometry.

An approach like that may seem too hard to develop. In a way, it undermines the foundations of physics as an "exact" science, putting it in the same row with the speculative disciplines like philology or sociology. On the other hand, such a comparison may be very productive, introducing physical notions of an entirely new character and stimulating the search for the corresponding experimental techniques, for mutual benefit.

Still, as long as we avoid too pretentious claims, certain aspects of manifold dynamics can be comprehended within the existing physical theories, with minor modifications. For instance, admit that the local dimensionality of motion may vary from one point to another, just like any other physical quantity. For a while, we do not consider abrupt changes (similar to "bifurcations"):



Here, there is a "critical" point, such as the manifold is one-dimensional on its left, and two-dimensional on the right. Such effects can be introduced later either through singular potentials or as quantum transitions. So far, let the dimension of the manifold change continuously:



Physically, there is no momentary transition, but rather a smooth migration from one to two dimensions in some physically (but never infinitely) small active area (denoted with the circle in the picture). Within this area, the dimension of the manifold can be represented by a real number. Today, in the era of fractals and dimensional renormalization, we are generally accustomed to (at least formally) non-integer dimensionalities, and this continuality does not evoke any objections. Now, to describe, say, relativistic motion, we can account for varying dimensionality in a straightforward manner, slightly modifying the traditional expression for the (invariant) interval:

$$ds^2 = c^2 dt^2 - dx^2 \pm \lambda\!\!\!^{-}{}^2 d\nu^2$$

The dimensionality of motion (as opposed to the dimension of space) is described with the parameter ν, and we need some "fundamental length" $\lambda\!\!\!^{-}$ to bring the dimension term to the units of length. Right here, there is already much to discuss. Thus, the sign of the dimensional term may hint to two opposite branches of physics that might be selectable by the appropriate asymptotic conditions. In this model, such "negative" and "positive" areas are utterly incompatible, which does not forbid their interaction via an additional level of hierarchy, or a quantum correlation. The correct choice of the sign for our branch of reality is a matter of thorough experimenting.

Note, that, for the negative branch, the sign of ds^2 can negative for very small displacements $(dx \sim 0,\ dt \sim 0)$; this might be a serious argument in favor of the positive branch, but also, as an alternative, an indication of some additional restrictions on the form of "physical" trajectories within the negative branch, as compared to the positive branch, which makes their physics very different.

As one can easily see, with the negative sign, the form of the interval much resembles the historical Kaluza-Klein approach, the predecessor of the modern string theories. However, there is an important difference in interpretation: instead of an abstract space in the background of physical motion, I suggest a revision of the very notion of dimensionality, allowing for its changes in physical interactions. Today, "theories of everything" are already showing the signs of stagnation due to the same conceptual difficulty as in the early 5-dimensional extensions: too much arbitrariness. It's fine to have enough freedom in our theorization; however, an excess of redundancy brings in an *ad hoc* air that has never been thought of as a merit. With the dimensional interpretation of the "fifth dimension", we can retain certain useful results, while avoiding the deadlock questions as to their nature and origin. As we will see, this new "coordinate" is entirely different from space and time; moreover, its introduction will essentially change the structure of the spatial part of the interval.

In the positive branch, the dimensional term is "time-like", and we recollect the old idea of a multi-time formalism for a relativistic treatment of many-body problems. Indeed, in a system of N material points, the formal number of the degrees of freedom equals $4N$: one time and four spatial coordinates for each particle. Depending on the way we impose the relativistic constraint, different theories will emerge; some of them may incorporate two or more time dimensions. However, here again, it is the difference in interpretation that matters. In the dimensional extension of the interval, the last term refers to a specific quality other than mere space-time organization, a new level of the same hierarchy. A few words about the levels of time can be found below; still, the far-fetched consequences of physical branching in the dimensional extension are to be examined elsewhere.

Personally, I suppose that every formal possibility is practically implementable. Otherwise, we just could not have fancied it. The world behaves with us exactly like we behave in the world. As soon as we learn new behaviors, we discover a different world.

To proceed, note that I do not use the "reduced" time $x^0 = ct$, like in almost every other text on theoretical physics. Even with the units chosen to bring the speed of light to unity, the factor c is still implied in the equation for the interval, to distinguish time from space. When we establish a correspondence between two physical (or any other) quantities, this does not mean that these quantities are of the same nature; otherwise, the very search for correspondence would be out of question. The invariance of the interval (which, probably, needs to be reinterpreted in our case) is just a kind of physical constraint (justified by the practically established constancy of the speed of light). It has nothing to do with reducing space to time, or the other way round; conversely, one might say that this reduction is only possible under the condition of the invariance of the relativistic interval (in the presence of the constraint). As we add yet another term to the expression, the physical nature of this equation becomes evident. In principle, there may be more terms (just like "chemical potentials" enter the second law of thermodynamics), for the invariant quantity to incorporate contributions from many physical processes other than mere displacement; in particular, our simple model also invokes the changes in manifold dimension. Of course, the presence of a units-reduction factor does not make variations of dimension into a kind of distance.

For distances and durations much greater than $\lambda\!\!\!^{-}$, the last term is negligible, and we are comfortably back to the usual dimension-static relativism, treating the threshold of dimension change as an impenetrable singularity, similar to the "relativistic barrier" or the Schwarzschild sphere.

Now, we come to the principal question: why should one add the dimensionality change term as a quadratic expression similar to those for space and time? It seems quite probable, that the very idea of a distance should be adjusted to variable dimensions, transforming the geometrical invariants into something entirely different, which would give the ordinary interval in the limit $\lambda\!\!\!^{-} \to 0$. The example of the formula for velocity addition is always at hand.

The first (trivial) answer is “why not?” This is a very crude model applicable to the inner regions of the active area far from its boundaries, and we can use it like any other, just to illustrate the possible lines of thought. It does not deny any generalizations, and even implies them. To provide a better justification, I need to make a brief lyrical digression into the origin of the variation principles constituting the basis of the modern theoretical physics.

In the beginning, when the human culture was yet syncretic, science did not much differ from art or philosophy, and in particular, the time for scientific specialization did not yet come. Physics, geometry, astronomy, psychology and physiology, geology and economy, subjectively dealt with the different manifestations of the same. The primary concern of this rudimentary science was about equilibrium. Largely depending on the freaks of nature, the humanity needed something solid to grasp. That is why the first ever scientific laws were essentially static, revealing stable structures in any motion. Numbers, geometrical shapes, celestial orbits *etc*. were the instances of the universal equilibrium; later philosophers took them for pure ideas built in any perception and hence determining the form of thought.

For my purpose, it is enough to indicate the practical importance of right proportion in material production and economy. Ancient architects had to adapt to the force of gravity; all kinds of levers were largely used to compensate for muscular insufficiency; any measurement at all relied on the relative stability of both the thing to measure and the instrument. The appearance of mathematics and logic was mainly an attempt to fix the forms of reflection in the same equilibrium manner, thus laying the foundation for any academic (well-balanced) science.

To find the balance, the guiding idea was to slightly shift a piece in the whole[7] and see what happens; for stability, the system must tend to return to the original state. When the dissipative factors are small, it may take quite a while for the transitory processes to subside; in the limit of zero friction, the system will infinitely keep its motion, but it will do it in a regular way! This is a new kind of equilibrium, which can formally be attributed to the presence of some auxiliary terms responsible for the observed dispersion in the configuration space. In the early dynamic models, forces were introduced on that compensatory basis, to preserve (at least formally) the overall equilibrium of a system in motion. Today we use the same equilibrium considerations minimizing the value of the action functional along a bunch of similar trajectories. The very presence of such a stability obviously implies a number of symmetries (that is, the range of admissible variations).

Mathematically, an equilibrium point is characterized with zero first derivative; any deviations from the (local) minimum must average to zero, and it is only the second-order terms that may have any physical significance. In particular, for a physical space, the definition of distance must combine the squares of displacements; otherwise, the motion will not be stable enough to form any observable pattern. Of course, this does not deny the possibility of such “unphysical” events; however, to practically cope with them, we need yet another level of hierarchy, a new kind of stability as a basis for new physics.

For an extra hint, take the well-known phenomenon of diffusion, where the expected distance form the origin is proportional to the square root of time. Similarly, the standard Schrödinger equation is linear in time, which implies a mixture of the different levels of description; however practical, such “mixed” models are not entirely consistent, and we have to justify them as approximations of a more general theory.

That is why accounting for variable dimensionality will involve the squared deviation of dimension, on the same footing with all the rest. We speak about a physical equilibrium, with all the variation principle ideology kept intact. Just introduce a small fundamental length, and do anything as before. More complex equations might arise outside the active area, when the inner motion and outer asymptotic are considered in parallel; such multilevel physics is certainly possible, but I am not going to discuss it right now.

One could object, that the distances close to the fundamental length (where the variable dimensionality effects can be of importance) are anyway too small to allow classical description, and

[7] Compare the absolutely ubiquitous proofs by contradiction in mathematics. In the circuits of high quality, where the transitory oscillations do not die out, we observe an analog of the famous liar paradox.

quantum effects must necessarily be considered on that scale. This is a logical confusion. Quantum physics is all about correlation. It does not depend on the spatial or temporal scale. Yes, we first observed quantum behavior in microscopic systems; today, we admit quantum correlation in outer space, for huge astrophysical bodies, nothing to say about the usual human-sized objects like lasers, or the presumed quantum communication devices. Conversely, classical physics does not much depend on the system's size; for instance, cascades in atomic and nuclear reactions are quite classical in nature, and there is absolutely no reason to deny the possibility of ("quasi")classical behavior for very short distances and times. As soon as we can stage an experiment of the classical type, we do not need any quanta at all.

By the way, one could consider any quantum physics as built over some classical model (which is commonly referred to as "quantization"). In particular, the symmetry of the theory (the form of the interval) is to be chosen before we can introduce a quantum configuration space. Any modification in this (classical) constraint will influence the form of the corresponding quantum theory. In particular, adding the dimension-dependent term will significantly modify both classical and quantum predictions.

Of course, this approach is utterly incompatible with philosophical relativism denying the very idea of the physical systems and their interactions; there were numerous suggestions to replacing the objective order by mere psychological correlation *etc*. This is an entirely ideological choice, which is outside any science at all; it can hardly be too productive in the physics of space and time.

With the dimensionally-enhanced expression for the interval, general relativity can be introduced in the standard manner, through variable metric, which, in this case may also depend on dimensionality. A meaningful discussion of this generalization should be based on a clearer understanding of the meaning of the Einsteinian theory, which still does not seem to receive an acceptable (and logically consistent) interpretation. In the rest, I stick to the simplest form of the interval, though the conclusions may as well apply to the general case.

In a manifold of variable dimensionality, one cannot directly relate the local dimension with the number of independent coordinates. Dimension as a physical value is to be related to a hierarchy of degrees of freedom, constraints and the structure of the "observer", as discussed elsewhere. [8] The spatial displacement (or uncertainty) dx^2 is primarily measured along some trajectory (a world line), and it may be differently unfolded into the sum of individual contributions; such specifications determine the possible frames of reference. For the transition from 1-dimensional to 2-dimensional area (like in the above pictures), one will possibly consider simple two-component objects, with the "up" component corresponding to the fully unfolded 2-dimensional state, and the "down" component referring to the folded, 1-dimensional spatiality. Normalized to unity, this "spinor" will represent all the intermediate states, with the dimensionality between 1 and 2. This means that the relativistic coupling of space and time will also take two different forms, and we must consider a combination of the both. Similarly, if we need to continue a 1-dimensional trajectory into a 3D region, we'll have to add more components accounting for the different modes of unfolding; for instance, a representation with 2×2 matrices is intuitively attractive, with each of the two indices referring to the unfolding of the corresponding dimension. In the degenerate case of constant dimensionality, one component equals 1, and we arrive to the common representation of a frame of reference by a coordinate system. Of course, there are other possible frames built from less trivial mathematical constructs; however, all such representations correspond to the same physical reality, which does not depend on the way we fancy it. As usual, both classical and quantum pictures are equally conceivable, as well as any their combinations. Obviously, physical laws will change their form from one component to another, and it is not too unlikely that certain interactions that we consider as different within the standard model refer to the same interaction on the different levels of dimensional hierarchy.

In my dimensional model, there is yet another hierarchy related to the nature of time. This temporal hierarchy does not directly correspond to the spatial hierarchy introduced above; rather, it develops in an "orthogonal" direction. In every frame of reference, there is a "physical" time correlated with the measures of distance. For layered distances, reference time is the same for any dimensionality.

[8] P. B. Ivanov, "Hierarchical Dimension" (1984) — *http://unism.pjwb.org/sci/mth/hde.htm*

This could be considered as a physical condition ensuring the integrity of motion. However, such metric time is not enough to describe the system's dynamics. There are two other levels of time that could be referred to as "inner" and "outer" time.

Indeed, always remaining in the equilibrium zone (that is, assuming the applicability of the variation analysis), we find that the traditional expression for relativistic action

$$S = -mc\int_a^b ds$$

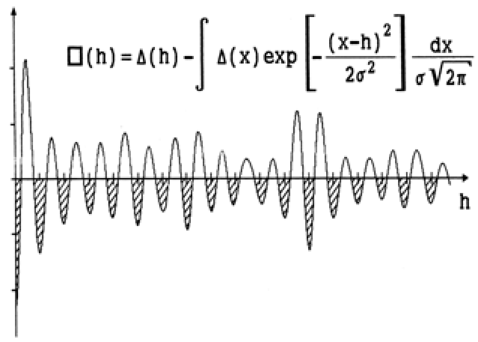
does not necessarily hold for the variable-dimension manifolds, since the "density" of trajectories may change with dimensionality (compare it to the functional of action in general relativity). Also, the initial and final point of the integration path may belong to the areas of different dimensionality, and there is no "inherent" ordering. We cannot, in general, speak of the interval as such, but rather about its local variations. Note that the factor *mc* is no longer convincing in the dimension-dependent case: first, the speed of light here plays a more modest role, along with the other "structural" constants, and second, the rest mass as a global (topological) characteristic of motion must certainly be replaced with a more flexible construct reducible to the constant mass in the regions of constant dimensionality. Still, as the manifold is deemed to be connected, there are physical trajectories between any two areas (on the global scale), so that one could proceed with an action functional taking a slightly modified form:

$$S = -\int_a^b \frac{Ds}{D\tau}\rho(\tau)d\tau$$

This assumes, first, an integration parameter that marks the physical stages in the transition from *a* to *b*; here, $\rho(\tau)$ represents the inner structure of the active area that cannot be entirely eliminated in any frame, and it is only in the limit of constant dimensionality (in the asymptotic region) that this density becomes constant (effectively eliminating the need for any additional time levels). As the structure of the integrand is related to the overall picture of interacting particles and fields, the integration parameter τ can easily be interpreted as a kind of upper-level time, imposed on the physical system by the apparatus setup; that is why I call it the "outer time". Each tick of this clock assumes an equilibrium state achieved after all the possible "probes" have already been damped (or averaged out). These transitory processes develop on a lower level folded in the physical (metric) point; when we speak of a variation, a small perturbation *etc*., we implicitly refer to that "inner" time.

The distinction between these three levels of hierarchy is relative: shifting the focus of attention up or down, we can make inner or outer time quite physical, while the former physical metric will give way to some other observables. For a far-fetched consequence, one might think of the relative nature of the distinctions between the interactions of the present standard model, as well as its partial reproduction on a different level, in a quite different context.

For a margin illustration, take the pitch levels in music.[9] Each historically possible scale can be represented with a number of pitch zones, like in this picture for the common 12-zone scale:



The shaded areas correspond to the really perceptibly musical tones, while the possible (in this scale)

[9] L. V. Avdeev and P. B. Ivanov, "A Mathematical Model of Scale Perception", *Journal of Moscow Phys. Soc.* **3**, 331–353 (1993).

deviations from the “exact” pitch belong to the level of inner time; the outer time will be associated with real intonation (sequences of notes and harmonies).

The interplay between the inner and outer levels is responsible for the observable mass spectrum. Indeed, consider a simple two-level mechanical system with the a relatively smooth motion on the higher level accompanied with very fast oscillations on the lower level. Physically, the inner motion will be represented in the expression for the interval (near the equilibrium) as an additional term proportional to its squared frequency; that is, as a kind of inner energy, and eventually a mass. This suggests a new line of thought in the theory of dimension-dependent metric: the changes in the manifold dimension could be related to its hierarchical structure, with the enhanced interval as above pertaining to the regions of restructuration (conversion of hierarchy). In this picture, the additional term for dimensional shift has much in common with Einstein’s idea of geometry produced by matter and material motion modified by geometry. In a way, this approach might be considered as a formal alternative (or complement) to general relativity. While practically all the experimental evidence remain within the realm of post-Newtonian approximation, the observable effects (like the rotation of the orbit of Mercury) might as well be explained by a change in the dimensionality of the physical manifold; some physicists tried to intuitively account for this effect slightly modifying the inverse-square law for Coulomb force and gravity, which is not entirely consistent and hence the results were not quite satisfactory. The idea of metric dimensionality might also remove certain conceptual difficulties from the theory of very heavy attraction centers (“black holes”) as well indicate the ways of bypassing the uncomfortable relativistic restrictions on the speed of physical interaction. In particular this may demand an explicit account for temporal hierarchies. In the simplest case, various multi-time forms for the interval are to introduce a hierarchy of “coupling constants”. Eventually, the hierarchical picture will serve as a kind of generalized dimensionality on any physical manifold: a specific hierarchical structure is to be unfolded in each point, while any transition from one point to anther will require a restructuration, a conversion of the hierarchy.

And, once again, this is a new approach to the very nature of physical dynamics: instead of discussing the admissible structures in a space of a fixed dimensionality, we say that there is no pre-defined physical dimension, so that the dimension of any particular physical process is dynamically formed as a result of that very process, in some practical context, in the vicinity of a local equilibrium point. Space and time will no longer usurp the status of the *a priori* frame of any reflection at all; other ways of ordering the hierarchy of physical interactions may be possible under appropriate conditions, penetrating the other sciences as universal paradigms.

Relativistic Illusion

There is science, and there are funny games, personal amusement. In science, we do not deal with manufacturing the tools and instruments: we just use them. Well, one might prefer certain brands to the others, but this does not make much difference. Afterwards, when the scientific product is ready, popular writers will explain what is really meant and how we can match it in our everyday life. Philosophers will justify the necessity of that very science, carefully concealing any pitfalls in the basic assumptions. The apparent contradictions are to be attributed to the weaknesses of the laymen’s intuition, and a new kind if intuition is to provide a finer amusement, just to launch yet another coil of abstraction.

Special relativity theory has inspired numerous popular explanations. For a working physicist, there is nothing to explain, since, in science, a conceptual framework must be postulated before we start a meaningful discussion, and it is this common platform that makes science meaningful. For the rest of the humanity, formal manipulations are said to be justified enough as long as they conform to the so called principle of relativity, stating that the overall picture of a physical system’s dynamics will be the same in all inertial frames of reference, moving with constant velocities in respect to each other. Unfortunately, most people are hardly aware of that this explanation only refers to the invariance of certain mathematical constructs under a class of coordinate transforms. Such relativity does not appeal to the heart of an average person, who would prefer palpable facts to any theoretical models, however perfect and beautiful. Theories come and go, while our acts remain basically the same. Here comes the other side and complement of the principle of relativity: the as famous correspondence principle demands that all the physical theories pertinent to the same physical domain agree with each other in its formal description.

Lack of understanding feeds all kinds of illusions. Which facts will survive a transition from one frame of reference to another? What is physical and what is not?

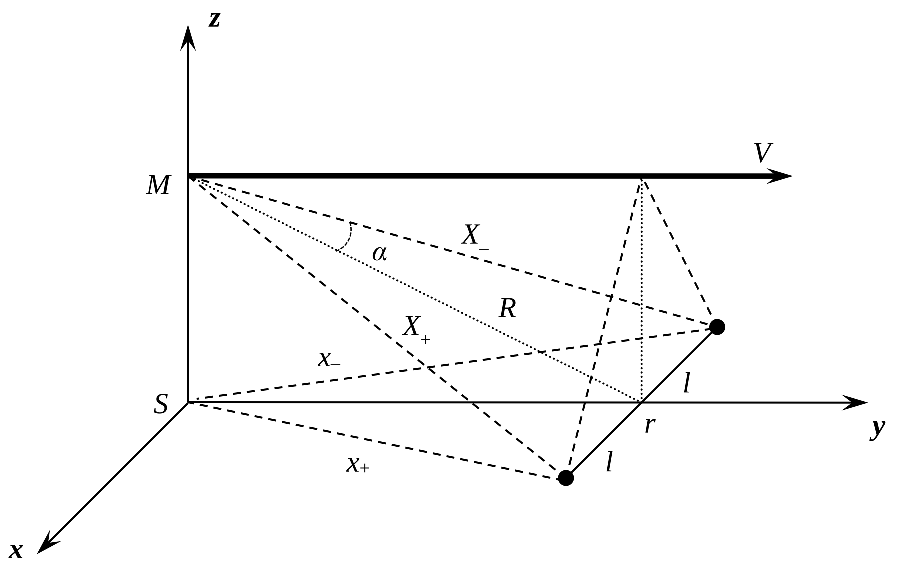
Take the simplest physical model ever, free mechanical motion. Slow down and think. Comparing the numerical estimates for lengths and times is a nontrivial activity requiring extensive procedural conventions. It seems like there is something more fundamental, a qualitative basis for quantitative comparison. When two observers perceive entirely different shapes, it's no use inquiring about the relative sizes of the details. If one observer detects an event, and the other doesn't, they can hardly compare the respective place and time. We have to admit, at least, that the two observers share some of their observations and are able to qualify them as referring to the same physical entity.

The next step is to pick out a particular common object and compare the overall character of motion in the same respect. This latter restriction may be important. Indeed, it is much easier to compare two trajectories than, say, a classical trajectory with a quantum system, or a statistical distribution. The spatial position (and shape) of the upper surface of a liquid column in a thermometer can be treated in a purely kinematic way, and we can trace its evolution with time; however, this is not exactly the same as temperature measurement.

To be sure, restricting ourselves to the same range of physical phenomena is not yet enough. With the same thing observed in different frames of reference, the observers are supposed to employ comparable observation techniques as well as interpret the results in a comparable manner. This may raise numerous questions about the validity of the corresponding reduction schemes. In the trivial mechanical model, we demand that the structure of all the frames of reference be the same. Three spatial coordinates and time will constitute the complete set of observables for every observer. The topology of the frame of reference is also universally fixed.

With all the precautions, we still cannot guarantee the overall agreement of the observed patterns of motion. As long as each observer entirely belongs to the corresponding frame of reference, there is no way to tell being at rest from steady (inertial) motion, and the inner scale of one frame does not need to comply with the scale of another. This may result in spurious forces interfering with the observed picture of dynamics, up to violating the very inertiality of the frame.

At school, we are told that a point steadily moving along a straight line in one frame of reference will also do that in any other inertial frame. But look at the picture below:



Let there be a stationary observer *S*, and a kind of solid rod placed in the *XY*-plane parallel to the axis *X* with the center positioned on the axis *Y* at the distance *r* from the frame's origin. There is another observer *M* moving relative to *S* along the stationary axis *Y* with some velocity *V*. It is traditionally assumed that *M* will see the rod steadily shifting towards the axis *X*, with a perfect accordance with the principle of relativity. The length of the rod will remain constant, and its ends will apparently draw straight lines in the frame of *M*, as it should be for the free motion of a material point.

It would have been so if the observer *M* saw the rod as belonging to the frame of *S* and moving entirely due to the relative motion of the two frames. However, there is no reason for *M* to associate the rod with the observer *S* and any frame of reference other than *M*'s own. In *M*'s place, everybody would observe a quite different behavior: some distant point gradually grows in an extended rod and then collapses back into a point. Observer *S* understands that the maximum size of the rod in *M*'s eyes corresponds to the position just above the center of the rod. By why should *M* care for somebody else's impressions? For *M*, the seat of *S* looks like emitted from the same original point (big bang!), eventually being lost in the negative infinity. Isn't it like spatially expanding and collapsing Universe, with the position of *S* playing the role of time? Or entropy, if you wish. To enhance the resemblance, admit that *M* can see nothing but the expanding and collapsing rod (plus, probably the ticks of the clock represented by some signals from *S*). For a small portion of the whole story, with linearized dependences, we obtain the familiar cosmological picture.

By the way, the expansion and collapse of the rod in *M*'s frame of reference is associated with certain acceleration, and hence forces. Are they spurious effects or true physical interactions? *M* has no evidence to tell.

A physicist would indicate that the calculated trajectories should exhibit certain numerical peculiarities that could be used to restore the overall picture of the two relatively moving frames of reference. The exact shapes of the dependences suggest a quite definite interpretation. This is how we deduce the global movements of the celestial bodies from our geocentric observations.

Is that convincing enough? Yes, for a physicist. A layman would wonder, why we should employ this calculation technique, and not that, and why the very idea of a frame common for all frames of reference should enter our heads. Isn't it against the principle of relativity? In a way, Einstein followed that very line of thought, to come to general relativity. On the other hand, to get a representative profile, we need to aggregate data from qualitatively different sources, which is quite an endeavor for a local observer (with a lifetime negligible on the cosmological scale), even in the trivial case, comparing the devices like a rule and a clock.

Numerical calculations are always questionable. They can be interpreted in many ways, and a slightest shift of perspective may result in a qualitatively different shape.

Indeed, just consider the popular example of the train passing a platform. When a passenger drops an apple, it will fall along a straight line, according to the notes of the passenger, while a person on the platform will see a curve. In a rotating frame, this curve would become a spiral. Are these shapes different? It depends. Thus, topology identifies all the shapes that can be continuously transformed into each other; still, an abrupt turn of a vehicle may cost somebody a life.

In other words, the validity of any calculus essentially depends on the context. To compare frames of reference, we need a common basis, a higher-level frame. To compare such upper frames we need yet another level of hierarchy. The overall picture of the world will vary from one such unfolding to another. The quality of the objects belonging to a specific level (and hence the range of their quantitative estimates) can only be defined in respect to a particular layered structure. If we guess it right, we call it a physical law. A wrong guess is mere illusion. Still, physics can never judge what is right or wrong; to do science, we need something beyond science. Within a wide class of activities, it may be important to know how it goes; in many other activities, we'd rather stick to how it feels. Restricting ourselves to a superficial impression, we lack depth; overestimating the power of science, we lack wisdom. However attractive in their apparent universality, our theories may be as illusory as a naive vision of a passer-by. Imposing the familiar modes of action regardless of the inner nature of the object is no better than sheer fantasy. Universal consent is not yet universal principle. To cultivate a bit of reason, let us never forget that our picture of the world (and the physical world in the first rank) isn't but relative, with all its frames and illusions being both a reflection of the current level of our local development and an indication of the movable nature of any horizon, as any relativity is relative. Including this one.

Hierarchical Observations

Competition means poor competence.

As long as I do what I think is right, why should I care for anybody else's opinion? And as soon as I get engaged in a discussion, I am certain to partially accept the opponent's standpoint; otherwise, we would have no points of contact. Well, nothing criminal in a partial engagement. It is only taking it for serious that makes trouble.

It is especially dangerous to talk to mystically inclined former professionals who sacrificed their professionalism to a philosophy of a stinky kind. Trying to do philosophy without enough competence beyond science is as vicious as doing physics on an entirely philosophical grounds. The two areas can efficiently collaborate sometimes; this is no reason for an official marriage.

Scientific theories (provided they describe at least something) do not oppose each other; rather, they refer to the complementary aspects of the same reality. Some techniques are useful here, somebody else's approach work elsewhere. Why not admit that both contain a grain of truth? Truth is many-faceted, and nobody can be true in any respect at all.

The foundations of science are outside science. A scientist does not need to justify the choice of a particular model. All we are expected to do is indicate the observable effect and suggest some ways to check. When things start behaving in a predictable manner, just toss the tool to engineers and applied scientists, and proceed with another model, for a different case. Fundamental theories are never invented just for fun; normally, they grow from a difficult problem that cannot be solved with the existing conceptual luggage and hence needs an advanced formalism. The technical details would promptly get in place, and let philosophers habituate the public to the basic facts.

There is, however, a minor issue of reflexivity. In a way, scientists are too a part of the public, and they like being given a treat. Moreover, (high) school teachers need a number of mental hooks for the students to overcome the first shock and move on to the technical knowledge without too much pondering on methodology. Philosophy is too circumstantial and time consuming, while practical needs cannot wait. So, let us take the first affordable explanation and stop considering any alternatives. This is how quantum mechanics got stuck to the Copenhagen interpretation, however absurd and incoherent. The thing's done, we can proceed with science, as our *how*'s do not depend on *why*'s.

Nature reveals itself to scientists through all kinds of invariants. In a sense, a fundamental theory is an invariant of many philosophies: no revision of the foundations is acceptable unless it conforms with the already established standard. So looser the grounds for philosophical debate, unless we are going to (indirectly) support certain political movements that have nothing to do with science.

Among others, Einstein did not much praise the philosophical concoction by Bohr and Co. Wise enough, he did not try to beat Bohr on their quantum field; he only indicated that the present recipes must be either nonlocal or incomplete (how do you do, Mr. Gödel?). Any attempt to go further in this shaky area would be a concession, and Einstein wanted no trade-off.

Much later, Hugh Everett III approached the foundations of quantum mechanics from a different angle, which automatically put him off any academic career (though, possibly, he did not ever consider becoming a physics guru). Did it really change anything? Arguing against Bohr, Everett took exactly the same position, and the difference between the two interpretations is mainly terminological. Thus, both considered measurement as a kind of interaction between the quantum system and the classical observer; however, for Bohr, the observer was a mystical force that makes a superposition state "collapse" into one of the observable outcomes, while Everett pretended to describe the observer and the object as parts of the same world, with every act of measurement splitting the world into several clones, with each cloned observer registering a specific quantum state, and this lead to a mystical picture of a cloud of non-interacting worlds. Later, for this separation, the followers of Everett coined the term "decoherence", which means exactly the same as Copenhagen-style "collapse". All the other seekers retain the same core discrepancy between the quantum and classical levels, and one can read in a standard theoretical physics course (Landau):

> […] for a system entirely composed of quantum objects, it would not be possible to construct any logically consistent mechanics. […] This […] is logically related to the fact that the dynamical characteristics of an electron can only come as a result of measurement […]

From this stand, one can never guess how a classical system differs from a quantum system. There are speculations on the "correspondence principle"; still, they only demonstrate that classical behavior can sometimes be obtained from quantum equations as a limit case, but the possibility and nature of "mixed" interactions (between the quantum and classical levels) remains sheer metaphor.

By the way, why should we take the correspondence principle as a one-way road? Yes, quantum systems may reach a classical limit (to comply with Everett's conjectures); but classical systems, too, may develop quantum behavior under certain conditions (as Einstein believed). The industry of quantum computing seem to perfectly support such an extension. Similarly, the relations between Newtonian and relativistic mechanics are far from mere low-speed (or low-energy) reduction.

Returning to the Bohr-Everett controversy, one is somewhat surprised to encounter all those "collapses" and "decoherence" in an apparently linear theory. We perfectly know that any furcation is due to inherent nonlinearity. Any dynamics will be quite smooth until we explicitly introduce nonlinear terms in the equations of motion, initial and boundary conditions, or as an outer constraint. A closer examination reveals the machinery of magic: the very distinction of subsystems within the whole leads to a significant modification of the original theory. This is a very general statement, but here, a simple quantum-mechanical illustration is enough.

A system *W* with the Hamiltonian *H* evolves in compliance with the standard equation of motion:

$$\left(H - i\hbar\frac{\partial}{\partial t}\right)\left|W\right\rangle = 0,$$

with the overall state vector being an integrity comprising anything at all. All such vectors constitute the configuration space of this all-embracing system. So far, everything is linear and smooth (assuming a regular Hamiltonian). Now, let the system *W* contain a subsystem *P*; the rest of the system will then be treated as its complement *Q*. Formally, this can be represented by splitting the whole configuration state into a direct (Cartesian) product of subspaces pertaining to the subsystems *P* and *Q* respectively:

$$\left|W\right\rangle \to \left|\begin{matrix}P\\Q\end{matrix}\right\rangle = (P+Q)\left|W\right\rangle,$$

where the projection operators *P* and *Q* are defined as follows:

$$P\left|W\right\rangle = \left|\begin{matrix}P\\0\end{matrix}\right\rangle, \quad Q\left|W\right\rangle = \left|\begin{matrix}0\\Q\end{matrix}\right\rangle$$

Any projection is an essentially singular operation (similar to the well known Heaviside step function). Our theory would still remain linear, if the subsystems had no relation to each other. Unfortunately, this not always so; moreover, most often, this is not what we really want! For interacting subsystems, the complete Hamiltonian takes a block-matrix form:

$$\begin{pmatrix}H_P & V_{PQ}\\V_{QP} & H_Q\end{pmatrix} = PHP + QHQ + PHQ + QHP$$

The original regular Hamiltonian is thus expanded into a sum of essentially nonlinear terms, and one can expect almost anything! Just split the world *W* into the observer *P* and a quantum system *Q*, and get all kinds of dynamical peculiarities, from topological intricacies to violent furcation. The other time you might wish to consider a different splitting, and you'll get an alternative picture of the same one and only world. There is no need to collapse or clone: all the possibilities are already in there, as the complementary aspects of the whole.

Initially unstructured, our universe has unfolded into a two-level hierarchical system: an integrity on the higher level, interacting subsystems in the background. In the same manner, any subsystem can develop into a hierarchy, so that both the observer and the object are hierarchical. Suppose that the object (a classical or quantum subsystem Q) is unfolded in a number of sub-objects, and some of them may refer to higher-level dynamics, up to the dynamic of the observer. Then a trivial tree-like structure will twist into an intricate topology, and lower-level contributions will no longer be just minor corrections. Modern physics has developed extensive regularization techniques to cope with this problem.

Once again: it does not really matter, which language we employ to explicate this two-level scheme (the level of integrity + the level of interacting subsystems). The conclusion will be the same. Normally, we engage much more components, with the resulting sequences of subspaces being discrete, continuous, or even higher-cardinality "vectors". No wonder that almost any desirable behavior can be reconciled with the same fundamental theory (or, rather, a paradigm). When people badly want something, they'll find the way to get it.

Just to hint to a possible branch of discourse, consider the highly-degenerate limit $H_P = 0$. Isn't it much like a classical observer that can influence a quantum system's behavior, with no back effect on the observer's structure and dynamics? The dimensionality of such an observer's configuration space will determine the possible outcomes of any measurement, so that the observer's interaction with the quantum system is to result in some statistical distribution. This limit could hence be called space-like observer, as thus we get the idea of the overall organization of nature. Yet another illustrative example is provided by the limit $H_P \sim \hbar\omega \neq 0$, which (according to the equation of motion) makes the observer a kind of clock, the frequency ω determining the "time pace" for the system observed (the scale of consideration). Finally, the doubly degenerate limit $H_P = 0$ and $H_Q = 0$ is a good model of purely classical measurement.

In this view, the incoherent Bohr-Everett debate collapses to nothing. There are different ways to introduce nonlinearity in the scheme of measurement, and each solution is good for something, provided we do not forget that no differences can be definable except within the same, and any specific hierarchical structure assumes other structures to unfold where appropriate. Neither of such "biased" representations can exhaust the diversity of the real world, which may occasionally manifest itself as a quite different system of layers, with some peculiar definition of the observer. Since the distinction between the object and the observer is relative (so that the object can as well be said to observe the observer), one could fancy entirely observerless hierarchies, the world as it is, which serves as an objective background for any cultural reality. It is important that every time we find something in the world, much more is yet left to find. We cannot expect nature to always follow out caprices.

To be more specific, let us recall the universal prejudice that quantum measurement reveals one of the possible states of the object. Not at all! All we can affirm is that, after the act of measurement, the observer will be found in one of the possible observer's states (for instance, the positions of the pointer on a dial, or the sets of spectral intensities). In our quantum example, we refer to the eigenstates of the observer Hamiltonian H_P . Nothing can be said about the resulting state of the object (as described by the residual Hamiltonian H_Q). Moreover, if some classically observable effect required a definite state of a quantum system (which is a very strong demand, indeed), the system would be certain to leave that state in the course of measurement, and hence what we measure can never refer to how the object currently goes, but rather to the way we employ the outcome, the trace of our interaction with the object.

Popular writers readily draw pictures like

$$(\sigma_+ + \sigma_-)\varphi \to \psi_+ + \psi_- = \sigma_+\varphi_+ + \sigma_-\varphi_- ,$$

meaning that, when (say) an electron in a superposition state impacts the observer in some neutral "vigilant" state φ, we get a superposition of two possible outcomes, each referring to a "correct" measurement, the perfect correspondence of the experimental value to the real nature. Then they either invoke "collapse" of the superposition into one of the possibilities, or admit a parallel evolution of the non-intersecting "worlds" after the rite of decoherence… The logical version of the same would rather picture the final state as $\sigma(\varphi_+ + \varphi_-)$; that is, a direct product of a superposition state of the observer (obviously identifiable with the experimentally observed spectrum) and an undefined state of the quantum system (which may occasionally run into another observer and show up as anything at all [10]). All the "entanglement" talk is then sheer advertising. We cannot keep a quantum system in a definite state after measurement (or any other creative act). Even worse, any interaction with a classical system cannot lead to pure (superposition) states: it will always result in a mixed state (for instance, as described with a density matrix). The system's "preparation" to measurement is an indispensable part of any experiment. This is how we suppress all interactions outside the scope of interest (thus unfolding the object's hierarchy into a specific configuration space). For repetitive observations of the same kind, we need to physically bring the system back to the incoming configuration, "preparing" it again and again.

Speaking of the structure of the object's configuration space, we already assume an unfolded hierarchy far beyond the primary separation of the observer and the object. That is, to build a meaningful physical theory, we need explore the structure of the object, splitting it into all kinds of interacting components and assuming that only a few of them participate in the intended measurement. Some parts may be classical; some other parts will demonstrate quantum behavior. In any case the number of projectors involved can be huge; therefore, any linearized theory is nothing but a practically acceptable approximation.

This, once again, puts us in the context of philosophical controversy. Under-philosophers with a physical background appeal to "reality" to substantiate their speculative constructs. Philosophizing Everett did not see that his objections to Bohr merely revived the struggle of medieval "realists" against as medieval "nominalists". The both parties are wrong, since, primarily, they reduce all the human activity to cognition, and then admit that our knowledge is comprehensive and perfect, identical to the world. In any case, representing the integrity of the world with the equation $P + Q = 1$, we can only focus on the observer part P, as we cannot know for sure the inner organization of the object of study. To account for the possible alternatives, we approach the object from many angles, measuring all kinds of complementary characteristics:[11]

$$P = \sum |k\rangle\langle k| = \sum |q\rangle\langle q| = \sum |\xi\rangle\langle \xi| = \ldots$$

With each choice, something (and, in fact, the major part) is left beyond science. Now look at the naive Everett's statement that it is only the complete wave function of the world that deserves the name of physical reality. Leaving aside the extremely narrow vision of the world understood as only one of the possible representations of the *observer + object* type, one could note that wave functions are no physical entities at all: they entirely belong to the observer as handy shortcuts for a specific attitude to the world. This is the way we see the world, and in no way the world as it is. Eventually, the same world has many other aspects that must be treated differently, possibly with no recourse to the quantum paradigm. In other words, our knowledge of any individual physical system is essentially incomplete, nothing to say about the knowledge of whole world. In physics, we are interested with a tiny portion of the possibilities pertaining to our practical needs; in the context of a different activity, we may describe the same with yet another physics, as incomplete, and as effective just because of that incompleteness.

In this way, we respond to one of Einstein's criticisms. Yes, quantum mechanics *is* indeed incomplete, just like any other physical theory is (including special and general relativity). The illusion of classical completeness is due to the spatial treatment of the observer as a non-changing background in which all the physical systems are embedded. Since classically moving objects exhibit the same structural invariance, the correspondence between the dynamical variables of the object and the quantities observed is basically a straightforward translation. On the contrary, quantum objects do not exhibit their inner motion to the observer, and no quantum theory can be complete in the classical sense.

Are there macroscopic systems that cannot be described within the classical paradigm? Lots. Any classical system at all will show an analog of quantum behavior in the presence of interactions that

[10] In general, to describe the system's behavior after measurement we may need a different configuration space and some other Hamiltonian. Strictly speaking, the same holds for any interaction at all, and that is why we can combine different complete projector sets to model virtual cascades.

[11] This implies unfolding the observer into a hierarchical structure.

cannot be exactly specified or controlled. Nonlinear dynamics pictures that as chaos; in hierarchical systems, lower-level interactions will influence higher-level dynamics in a quantum-like manner. Consider the well-known example of Brownian motion, with the average distance from the origin increasing as the square root of (macroscopic) time. This means that a combination of several independent processes of that type must be described by the superposition of the corresponding virtual amplitudes, while the observable intensities are to be obtained as squared amplitudes, according to the quantum rule.

This is a right moment to touch the issue of probabilistic methods in quantum physics, with their numerous mystical explanations. In fact, we can never observe any probabilities. Statistics pertains to our ways of data processing, and never to physical systems of any kind. There are physical events. If we do not discern individual events, we measure some aggregate features (intensities). The only difference between the classical and quantum pictures is in the manner of aggregation. With no interference between the individual inner events, the sum of intensities will represent the total intensity. When some interactions have to be considered as partially intersecting in time, quantum interference takes place. The propagation of a quantum particle is then pictured as a kind of flow, with the corresponding variation of intensities. Depending on detector thresholds (yet another nonlinearity!), the observer will either get a sequence of "random" pulsations, or a full-fledged spectrum. Virtually, the whole bulk of quantum physics (as well as classical statistical physics and thermodynamics) could be rewritten in a probability-free language; we do not need this notion in physics. While a working physicist is quite comfortable with the probabilistic slang devoid of any subjective connotations, politically engaged philosophers substitute physical notions for all kinds of spiritualistic ideas to justify social discrepancies with pseudoscientific blather.

It is exactly the introduction of unphysical notions that allows philosophical prestidigitators screw physics into whatever they like. It does not matter whether we adopt classical or quantum paradigm. Popular books never miss the opportunity to mention the mental experiment with electron spin states and their superposition, with the resulting "entanglement". Let us stage the same trick in a purely classical way. Suppose that we write characters 0 and 1 on two sheets of paper and put them in sealed envelopes, which are then delivered to the opposite points of the globe (or the Galaxy). For observers located in the destination points, very far from each other, the probability of finding 0 or 1 after the seal is broken equals 1/2. However, when one of the observers breaks the seal and sees the label 0, the far-away observer is certain (with 100% probability) to have the label 1; in the slang of the official quantum philosophy, the wave function has collapsed in no time, despite the relativistic restriction on the speed of signal propagation. We do not need any microscopic particles, or quantum fields; mere paper and pencil are enough.

The logical fallacy involved is that there are no probabilities at all, and there is only one (global) observer who can detect the quite deterministic state of the two-envelope system in several ways (specifically, opening either one or another envelope; there are also other, more sophisticated techniques). If the global observer could observe the process of putting the sheets of paper in the envelopes, there would be no need for any measurement; assuming that this part is beyond the observable (or computable) scope, we switch on to an incomplete theory with hidden variables of unknown nature. However, since the possible outcomes of measurement are subject to a global constraint (the assumption that only two options are allowed), it does not matter which exactly part of the system is observed; the rest is derived from the deterministic character of the constraint. This explains the illusion of nonlocality. In fact, the both envelopes are never independent, they are components of the same system located in a single point (the position of the global observer). The volume of the system may expand, but it does not move as a whole, and there is no need to send any signals. Considering two spatially separated observers is either a metaphorical reference to the distributed measurement instrumentation, or an admission of additional data available on each side: namely, the knowledge of the form of the existing constraint. In the latter case we get a local theory with hidden variables; otherwise, there would be no means of relating one envelope to another, and even no idea about the presence of anything at all except the local experimental setup.

Such global frameworks exist in any human activity at all. We cannot operate but within the current cultural environment, which often would impose severe restrictions as to what is practically permitted. In particular, no information transfer could be possible without a commonly accepted protocol. The common idea of probability as a summary of our expectations is thus perfectly grounded. And that is why the same data can be encoded in many ways and transmitted using quite different physical media. Without the cultural preliminaries, we would only contemplate a physical process developing on itself, regardless of any interpretations. In the quantum language, to refer to this contextual dependence, we would speak of correlation, coherence, system preparation; a classical description would refer to hidden variables. This is essentially the same.

Hierarchical approach explicates the relations between the global observer and the inner space of the system to observe (the object). However huge, all the inner space is contained within a single point for the (classical or quantum) observer; moreover, the very notion and structure of the inner space is only explicable in terms of the observer, who has to decide on the mode of observation (that is, the expectable results) before any experimenting. Note that the constraints thus produced apply to the inner motion of the object rather than to the observer; to describe observer involvement, we would need a higher level of hierarchy, and a "bigger" observer. In our scheme of classical "entanglement", we could introduced an intermediate level of spatially distributed (classical) observers with the light barrier constraint. Since the outcome of the experiment is only determined in respect to the most global observer (presumably sitting in the same origin point), the lower-level measurements would have to be conveyed to that decision maker for aggregation, and the overall procedure would take just enough time to comply with the classical idea of locality. For the global observer, of course, everything would still happen within a single moment.

As mentioned above, the inter-level relations are not trivial: an additional (mediatory) level can be introduced between any other levels, and several level can be aggregated into a grosser structure. This is known as hierarchical conversion. The choice of a frame of reference, or the specification of a quantum system, can serve as two typical examples. The integrity of the hierarchy is restored on a higher level, which implies certain rules for transition from one unfolding to another.

So far classical and quantum systems did no significantly differ from each other. Now, it is high time to dwell upon the principal source of quantum nonlocality, the indistinguishability of the quantum objects. In our everyday life, we are quite accustomed to practical equivalence: if there are several ways of getting somewhere, taking any of them will do. In the quantum world, it seems like, selecting one of the possibilities, we necessarily invoke all the others. We can never tell, which individual electron has been deflected up or down after passing through the Stern-Gerlach magnet: all the electrons of the incident beam are partially present in both the upper and the lower deflected beams. Formally, this interchangeability is introduced in the equations of motion using additional (anti)symmetrizing operators, which makes the system explicitly nonlinear. The principle does not depend on the nature (and even presence) of real physical interaction; the exchange terms are present in any case, determining the topology of the configuration space. For the same reasons, no spatial separation can eliminate exchange effects; formally, it looks like a kind of infinitely fast interaction which is not subject to any relativistic restrictions and hence is essentially nonlocal. This is a real mystery, but we cannot avoid it, especially in high-energy physics.

The very independence of exchange from the physical background suggests the thought of an artificial character of quantum exchange: it does not pertain to the object, but rather to the organization of the observer (including both experimental setup and the procedures of result aggregation). If so, classical systems, too, could be treated the same way. Let us illustrate it with a real-life example.

Suppose we are selling oil to a number of customers who load their tankers and pay for the quantity indicated in the bill of lading. Oil is delivered to the terminals from a number of production centers with some natural logistic delays. If the tanker were to be loaded directly from the terminals, that would mean a lot of anchorage time and huge demurrage charges. So, we first accumulate oil on a hub tanker for further transshipment to the destination tanker, in bulk. Now, as we expect several customers within a certain period, we load the hub for all of them, indicating the specific quantities accumulated for each. In the quantum language, the hub is in a superposition state, with the coefficients related to the contract volumes. When a customer tanker comes, we load it with the requested volume of oil, which will drive the hub in a different superposition state ready for the next operation.

The real magic begins when we consider that one portion of oil is no different from another: Whatever we give to any customer contains a mixture of volumes originally intended for many others, and what is left after transshipment contain a contribution from the supply of already serviced tanker as well! We can calculate the exact proportions, and they will dynamically change in the course of load/unload operations. Sometimes the hub gets empty; sometimes its load goes to a single customer; but in most cases, the contributions intended for different customers will be heavily mixed, hence establishing a kind of kinship for a half of the world! Taking in account that each portion of oil is delivered by an individual price (as fixed well beforehand), we come to the necessity of reevaluating the market value of the oil supplied, and the interplay of this “quantum” prices with the documented sale price is a major source of profit for traders, just like quantum interference fires lots of domestic or industrial devices.

Of course, there is nothing special in oil trade. One could as well consider preparing for shopping and collecting money for bread, butter, cheese, and apples, on the basis of preliminary price estimates. For some reasons, you may decide to buy only bread and apples, with the expenditures proportionally redistributed. Or, some other day, you might write a paper for a journal, using the fragments intended for other publications. And so on.

The message is clear: we need exchange corrections because we describe the state of the object in terms of observer states. Quantum electrons know about our calculation schemes no more than oil knows about the final consumer. From the very beginning, they do not exist separately; there is a compound object of some peculiar nature, which does no need to comply with our limited notions. As we artificially separate the parts where they are physically inseparable, this inseparability is to be accounted for in terms of explicit (anti)symmetrizing. If some genius will suggest a new formalism for the theory of closely coupled systems, the spurious interactions will disappear in no time. For instance, instead of considering electrons (or other elementary particles), one could speak about quantum currents with different characteristics (just like we speak about electron and ion plasma in the interstellar gas). As soon as individual electrons are eliminated from theory, there is no place for indistinguishability considerations and nonlocal exchange.

As indicated, most physical peculiarities are due to some nonlinear effects. However, we are to distinguish two complementary source of nonlinearity in any physical theory: the inner (objective) complexity and the (subjective) mode of interpretation. Practical experience unfolds according to both the objective aspect of the world and our habits or intentions. The emergence of a new paradigm is a result of cultural development in general.

Is that any different from the popular philosophy of emergentism? Some well-ordered structures appear in nonlinear dynamics as a natural consequence of physical laws; other structures seem to be introduced in an arbitrary manner, just like the above observer-like description of the object. As long as we keep away from the mystical emergence from nothing, the already known examples provide a sensible basis for improving physical theories (as a part of self-improvement in general). The key feature of the hierarchical approach is the relativity of any distinctions and their relatedness to a specific hierarchical structure, an instance unfolding of the same hierarchy. That is, we perceive things as they are for us within the culture, depending on everybody’s social position. In particular, the limitations of our theories are not mere illusions: they reflect a certain stage of development, and primarily, the overall technological level. Scientific discoveries come in favorable conditions, changing the world for us.

To conclude, what happens to the battle of interpretations? One many-faceted world instead of the chaos of randomly proliferating worlds. Coexistence of different implementations instead of arbitrary collapse. Natural description instead of observer-imposed artefacts. The relativity of quantum-classical duality and its reproducibility on any level of the subject/object hierarchy. A hierarchical vision of relativity. And, of course, the universal complementarity of viewpoints, aimed at increasing everybody’s competence, instead of dull and unrewarding competition.

Deceptive Physics

Since the school years (or maybe even earlier), we are used to associating physical objects with mathematical constructs; however, only the most naive will believe that such abstraction are what physical objects really are. On the elementary level, some prudent professors still try to explain the conventionality of physical notions to the students: there always exist certain characteristic thresholds determining the safe range for the measurable physical quantities; any theory at all would no longer be meaningful as we approach the limits of its applicability, so that to drive us to a different qualitative picture implying some other quantitative estimates. With all that, entering the course of theoretical physics, a student is bound to experience a kind of psychological shock: there is no matter of fact any more, as the “exact” mathematical methods are put on the top of the list; that is, physical intuition is to give place to mathematical sense. A smart formalism is then believed to necessarily correspond to something in nature, so that the esthetical pleasure and the admiration of the prestidigitator skills become the primary criterion of truth.

The general theory of relativity serves as a classical example. The famous Einstein’s equation has been introduced on a purely formal reason as the most general covariant structure containing the derivatives of the metric tensor up to the second order. The beauty has absolutely fascinated physicists so that almost nobody has tried ever since to discover a meaningful physics behind the formalism; all we can meet is but various excuses, bringing nature under the ready-made scheme. Quite similarly, modern suggestions of grand unification are most attractive due to the universality of the basic strategy of deducing all the observables from a common symmetry, so that the many ways of its violation would produce numerous physical landscapes. The method of theoretical physics mimics mathematician’s mentality: there is nothing but a formal theory, and all the rest can only be treated as it “models” littered with the implementation details.

From the scientific viewpoint, it is these minor peculiarities that are of real interest; we go into particulars seeking for significant deviations from the formal scheme. When an experimentalist doggedly tracks down any instrumental errors, an increase in accuracy is never an end in itself, or an attempt to approach a allegedly self-existent mathematical abstraction; the real motive is to come upon the limits of our current conceptualizations, to guess the moment when it’s hard time to stop it and switch to a different occupation. This is much like summing up an asymptotical series, or iterationally solving the equations for an essentially ill-posed problem: there is no sense in going on if any attempt to proceed would only worsen the result.

All the physical theories (with no exceptions) are only valid in this “asymptotical” sense, far away from any boundaries. When a physical parameter becomes infinitesimally small (or infinite), this is an indication of violating the limits of applicability: the formal model in use does not correspond to the real behavior of the physical system any longer. Truly physical theory is indeed a hierarchy of special models adjusted each to its own scale, and satisfying certain usage conditions. No formula, however elegant, can pretend to provide a perfect picture of the world; such impressive abstractions are mere metaphors, or witticisms. Nature can allow for some level of subjective dictates, for us to be able to arrange our affairs within an arbitrary pattern; still, one day, one is to get rid of the deceptive stereotypes, which is the more painful the deeper they have rooted in our minds.

The common-life prejudice of space and time seems to be one the most ingrown kind. We all perfectly know that everything happens somewhere and some time. The place we call a spatial point; a accomplished event is a label for a moment (or instant) of time. Later one could discover that the episode also involves many adjacent points; well, let us refer to it as a spatial area, with the reservation of the right to distinguish individual points whenever necessary. Similarly, lasting (spread in time) events take the place of simple instantaneity, though the (at least principal) possibility of detecting individual instants still dwells on us as a picture of durations built of infinitesimal ticks of the clock. Now, just impose the standards, denoting the points and instants with numbers; the rest will follow from sheer math… Mathematicians will gracefully lend us the appropriate formal constructs, such as the sets of the continuum cardinality. Since the abstraction of a number does not imply any physics, space and time appear to exist on themselves, regardless of any moving bodies or wave propagation; in this way we just "embed" any physics in a mathematical space, so that it is only the modes of the transition from one abstract point to another that can to be meaningfully discussed.

Lorentz, Poincaré, Einstein and other founding fathers of the modern physics are said to initiate a revolutionary denial of such prehistoric visions, for the theory of relativity to gain an entirely new physical sense. Does that correspond to what we finally get? Frankly speaking, the idea of the real existence of mathematical abstractions has in no way been affected: the only difference of relativistic mechanics from that of Galileo and Newton is in the abandoning the time-independent three-dimensional space in favor of a combined space-time with the signature (1, 3); it is into this abstract container that we embed all the physical processes, which, in this picture, are far from any processual character, rather resembling purely geometrical objects, trajectories and flows. One step in advance, two steps backwards. The considerations of general covariance bring no bright spots, as the material fields are only summoned to distort the same ideal space, which crookedness we identify with gravity, just for formal convenience.

To be honest, one has to indicate that working physicists were never entirely comfortable with all those conceptual strains. In the early days of the relativity theory, they made spontaneous attempts to explain things to the general public (and thus get more assurance for themselves). All in vain. By the voluntary decision, the junk has been swept under the cover, to get rid of the moral inconveniences once and for ever; let the fundamental structure of the theory be an *a priori* postulate. For a diffident pretext, take the absence of any experimental evidence for the contrary, in the span of many decades.

As a lucky turn, quantum theoreticians came up with a pack of tricky technologies that the public was even less capable to grasp. Once again, in its tender years, quantum mechanics seemed to entirely destroy the classical space-time reasoning, eliminating the very necessity of raising any clamor. Unfortunately, the relief was not but ephemeral, since the only difference from the classical case was in putting the same space-time inside the physical system, so that we can no longer measure it in any direct manner, satisfying ourselves with plausible conjectures. That is, yet another step off the meaningful physics towards the mathematical thickets. Well, there is nothing really new in principle; still, the lack of technical background leaves no choice to a layman beyond the blind faith in the competence of the sage ones. The scientific revolution did not dispel superstition, but rather fed it up to bring science to the edge of religion.

Well, I certainly lay it on somewhat thick. Nothing is yet lost. Practical demands are to introduce the necessary corrections, and the ends will meet anyway. Physicists are not supposed to know why. They've got a hell of their professional concerns, with no time left for a hardcore philosophy.

With all that, a few explanations may be quite appropriate in the popular literature (especially for children). Thus, David Bohm, in his book about the special theory of relativity [W. A. Benjamin, Inc., 1965], righteously indicates that the spatial coordinates and time have no sense on themselves; they are always related to some common (socially established) measurement schemes, appearing as an outcome of interaction between the physical system and the instrument. For such entities, that are not imposable *a priori*, but must be revealed in the course of a thorough analysis of experimental data, the thought about a nontrivial interdependencies of space and time is quite natural; in this context, relativistic theory should no longer bring about any psychological tension. If so, why not move a little bit further? To determine velocities, even more indirect procedures are to be involved, eventually expressible in terms of coordinate and time measurements. Why, then, not fancy the speed of light as an artefact based on the traditional instrumental setup? As long as we bind the technologies of determining length and duration to the process of light propagation, the constancy of that speed is a sheer tautology rather than a physical principle. So far, physicist have just nothing to compare. By the way, the dimensionality of space-time can be immediately related to the number of parameters required to describe electromagnetic phenomena.

No popular writers are that bold. They do not develop their oblique hints and quickly drop the introductory part, to proceed to computation; playing with numbers is much easier than search for the foundations of physics. Here, one could witness utterly anecdotic situations. For instance, the relativity of simultaneity and distances is often illustrated by a number of mental experiments in a geometry entirely based on the assumption of velocities much smaller than the speed of light; the results thus obtained are then triumphantly fed to the reader as the convincing evidence of the impossibility of faster-than-light motion; that is, absolutely, no other options! Logically, it is perfectly clear that light exchange between the bodies with their relative velocity higher than the speed of light will produce a very peculiar pattern which is to be separately discussed. In the same deceptive line, the usual derivation of the Lorentz transform on the basis of common symmetries and the constancy of the speed of light also involves implicit under-light geometry, in the critical points; that is why it can hardly ever be considered as convincing enough.

However, there are much deeper reasons for the instinctive rejection of the rude relativism. What seems the most unacceptable is the abstract identification of the physical space and time with mathematical constructs that could as well apply to almost anything at all. Still, in nature, there are physical processes, and human activities are essentially dependent on that. One physical process (or an activity) can be compared with another. With all that, treating real things and events as point-like is only possible in a very special context, with a specific choice of the scale. When something tiny moves slowly enough, we can trace its trajectory as a sequence of momentary positions, points. On the contrary, the motion of extended bodies with very high velocities may present an entirely different picture. The usual coordinate representation is a risky enterprise for the physical speeds comparable with the speed of the probing signal; the more so for much faster velocities.

Virtually, one can easily guess what needs to be adjusted. The already mentioned Bohm's book contains a brightly indicative phrase [Ch. XIII]: if the observer in the embankment measured the position of the rear of the train at one moment and the front an hour later, he could ascribe a length of 60 miles or more to the train, evidently an absurd result.

What exactly comes out to be absurd? As a matter of fact, we need to determine the length of an extensive object; there are no preliminary considerations to decide which values are physically acceptable and which are not. Admit that the resident observer's clock is graduated in millennia; one hour is practically nothing on this scale, and the train will virtually look "spread" over many miles of the track. For a train-based observer, the length of the stock will be much less than that, in the same time scale; this leads us to the idea of length contraction in moving frames of reference. In this context, simultaneity becomes largely relative as well; however this primarily depends on the typical dimensions of the objects and the observer rather than on relative motion. By the way, such relativity is entirely compatible with the common sense: when we say that a train is (for instance) in Paris, we are not only ignoring the lengthiness of the train (taking it as a point, in its entirety), but also Paris is understood as something integral and indivisible (though, on another scale, one could think of specifying the particular position of the train within Paris). Compared to the Solar system, Earth can readily be represented with a massive point; on the contrary, for a hypothetical observer from a nearby star, the variations of the Sun's luminosity due to Earth passing the solar disk would be a regular method for determining the relative size of the planet. Similarly, one day might mark an instant in the life's span, while being felt as eternity in agonizing suspense.

In the example of Bohm's train, the observed form of the train may manifest intricate variations depending on the railway timetable. The very notion of the train's length has no meaning in this case; in the best, one could introduce a quantitative estimate of the minimal and maximal diameter of the observable structure. Effectively, we thus observe the topology of a certain segment of the railway system; other trains (serving as physical probes) would extend the picture and make it more specific. In the general case, we need to account for the modes of motion, thus switching to a kind of phase trajectory incorporating speed variations and halts. Space and time will naturally intertwined in this picture, so that our observations, beside the structure of the railway network, also provide information on the actual timetable; within the range of its permanency, there is a physics of space-time invariants.

On the other hand, thinking of a train as an extended object, what do we mean speaking of the train's front and rear? For those who measure distances in Angstroms, the question is too far from trivial! Under certain conditions, the very idea of a spatial (or temporal) boundary may need revision, or should even be suppressed. Admit that, for a standing train, some spatial distributions will realistically represent its boundaries; still, one can never be sure that the type of distribution is to remain the same in the state of a rapid motion, or on a different scale.

That is, the illustrative absurdity primarily refers to the idea of the absolute character of spatial points, their infinitesimality, regardless of the chosen scale. A physical point on itself can be of any complexity; as long as this inner structure does not pertain to the current task, we treat this system as a point. In real life, any "point" can be unfolded in large area as soon as our practical needs demand accounting for the underlying structural features. In other words, geometry and topology are not the absolute attributes of the world, but rather a characteristic of the particular mode of motion, an effective definition of a physical system. As long as our practical manipulations obey certain rules, the physics of the matter will show up as a set of invariants; approaching the limits of the model's applicability, we are bound to introduce significant corrections, or entirely revise the theoretical framework. For example, the notorious relativistic contraction of lengths and durations with the growth of a body's speed is sure to eventually violate the structure of the working space-time scale, so that the too short segments collapse to zero within the existing uncertainty; this demands a different experimental setup, with the former boundaries either becoming essentially distributed or entirely irrelevant and meaningless. Of course, along with coordinates, the same holds for any other physical values, such as mass, charge, potential, temperature, the number of particles *etc*.

The choice of the basic and derived physical quantities is no less relative. Thus, admit that velocity is defined by the ratio of a distance to a duration. Then, with both lengths and durations only determinable up to the characteristic parameters of the scale, speeds too must logically be treated as conditionally measurable, so that the constancy of a speed value in any transitions from one frame of reference to another is only meaningful in a macroscopic sense, far from the critical durations and lengths. For very short distances, one has to account for boundary effects; with times below certain values, the dispersion of the measurable speeds may grow beyond any limit, and the notion of an exact speed is to be replaced with some speed distribution. If, however, it were practically important to fix the exact values of a speed, this would mean that either distances or durations should be treated as secondary quantities, related to the motion of something with that *a priori* constant speed. The scales of time and length would then be interdependent, for any overall scale change to be effectuated in a consistent manner. Speaking of a constant speed, we actually demand that the chosen velocity scale admitted its precise representation with a number, while the physical system remained far from too small velocities, and consequently there should be a higher limit for any speed value. No need to remind that, like any physical value at all, velocities can be determined in respect to all kinds of scales, and any constancy cannot be but an abstraction.

Mathematics is justifiably usable in physics, provided there is a clear understanding of what exactly we are going to study (or employ). The structure of science is to reproduce the actual conditions of observation (or exploitation), so as to obtain a qualitatively correct picture of what really happens. Scientific formalization is never entirely abstract: it corresponds to the organization of a specific activity. For instance, when a small body (a physical point) moves too fast, a human observer cannot visually track the individual displacements and, instead of a point, sees a track, a segment of a line gradually drifting in the field of vision. The speed of the signal that we use to determine the position of the point (here, this is visible light) is high enough, and we locate all the intermediate positions; still, as the rate of image processing is much lower, the geometry of the observable motion will be determined by this strongest restriction. For some modes of motion, the transversal sixe of the moving body will be much smaller that longitudinal; one could thence conjecture that the thickness of the trail gives the true size of the body, while the observed lengthwise extension is mere artefact, instrumental effect. Still, like any hypothesis, this one is yet to be carefully validated. Say, if we get an instrument with smaller processing delays and find that the longitudinal dimensions significantly decrease, this supports the point particle assumption; on the contrary, if there is no drastic contraction, we have to conclude that the physical system is a finite-length filament. Any indirect observation schemes are, of course, possible as well; this is a usual (albeit somewhat risky) practice, to compare data from different sources. Ideally, to confirm the point-like nature of a physical object, we need a measurement device with the inner delays much less than the time necessary for the object to shift by a distance of the order of its transversal size. This is the obligatory condition for us to be able to speak of the position of a material point, and its spatial coordinates. With no means of increasing the temporal resolution of observation, we will have to account for the spatial spread of the object as a physical fact.

Such an approach may seem to reduce physics to mere optical illusion, while in reality… Still, what do you mean by "reality"? Thus, having established that a truck is to be observed within a certain block of space during some finite time, we should not get in there just for time said; otherwise, the physical fact may be aggravated by a medical incident (probably lethal). For practical decisions, the "true" physical size of the truck is of no importance; all we need is the mode of motion. Provided a theory predicts the point-like behavior, one might try to cross the track in a pre-calculated lucky moment; in fact this means becoming yet another physical instrument operating within a different scale and therefore capable of elaborating (albeit with the experimentalist's life at stake) our scientific model. Nothing subjective about this reasoning: substituting a human observer for any physical body would change nothing.

However, the temporal resolution of an instrument is not a mere numerical estimate. Any human activity develops on many levels, each with its own scale, characteristic lengths and times. Sometimes, time delays between the consecutive measurements are much shorter than typical times of the system's motion; that is how we register the system's "momentary" states. In other cases, the system may go quite a way from one act of observation to another, and its motion will then appear as a series of leaps; under certain conditions, there is a kind of "stroboscopic effect", a seemingly stationary structure. Quite plausibly, the observable space-time is but a kind of such an illusion! Indeed, to be able to measure anything, we get in resonance with some physical process and all the rest refer to this global formation, a frame of reference. Yet another observer would build his frame of reference in his individual pace; still, if we do it on the basis of the same referent process (for instance, light propagation), our frames of reference somehow correspond to each other, with the optional possibility of formally translating any measurement results from one language to the next (of course, with the due precautions about the compatibility of the scales and staying in the inner area, far from the limits of the model's applicability).

Following on, we conclude that, for each physical model, there is a number of dedicated scales supporting our capability to produce any meaningful (physically verifiable) hypotheses. Nature knows no absolute scale equally applicable to any physics at all. Physical interactions do not merely influence the structure of space-time (its metric, connectives, curvature); they rather give birth to space-time as such. Thus, the Coulomb law may well be interpreted as a *definition* of space in electrostatics: the squared distance is inversely proportional to the force of interaction. Similarly, the length of a road is determined by the wayfarer's fatigue (the work spent); the time on the way is related to the level of the traveler's involvement in the motive effort. Even the banal application of a rule is a kind of motion, from one mark to another.

A simple example: the swing of a pendulum determines the space of the possible positions (the angles of deflection). Add here an accurate enough clock to get an impression of a continuous space. However, due to the variations of the (angular) velocity as an effect of the pendulum's interference with the clock, the points of this oscillation space are not equally spaced , which result in a dynamical metric ("gravitation field"). Measuring time with a significant temporal discontinuity could bring about an apparent lattice structure, making the motion of the other system resemble chaotic wandering in that grid space.

Just to get more food for thought, consider the formal reduction of the angular speed to zero on the borders of the possible deflection range. As we have already seen, in nature, there is no such thing as a perfect zero; so, what could we see in a different scale? Judging by superficial logic, there is no other choice: one has to stop first, to start moving in the opposite direction… Well, just recall that it is only in mathematics that a harmonic oscillator is (by definition) what obeys the equation of the harmonic oscillator. In physics, we only use a mathematical abstraction within the range of its applicability, with no far-reaching allegations. In a different scale, the model of harmonic oscillator may become less realistic, and we'll have to fairly consider a physical pendulum, working out the boundary details, up to binding mechanics to thermodynamic considerations. Eventually, with a yet deeper insight, the very notion of a momentary deflection (a spatial point) becomes physically meaningless, as the pendulum may take several positions at once (like a quantum object, or anything like that).

Now, let us get back to Bohm's trains for a while. As expected, the physical simultaneity of detecting spatial positions and the momentary geometry of a train are essentially dependent on the scales applied, and observable motion can, in some cases, appear as a spatial structure. A universal space-time common for everybody can only be an illusion, an artefact, as commonality in the construction of a frame of reference is yet another abstraction. However, the motion of physical systems does not stick to this (formal) diversity. Our mental experiments pose the hardest problem ever: what do we actually mean by the notion of a train? How a piece of matter observed in many places in a number of time moments by different observers can figure in theory as the same and only object? In everyday life, things do not just move from one place to another; they tend to drastically change! Can a human being be treated as the same person entering a different age? Well, admit a few additional cars get coupled to a train at some intermediate station; will it be the same or another train for an outer observer? To judge by the train number in the timetable, there is no difference; physically, we have to cope with a different geometry, and it is not obvious what should be taken for the train's length in the general case. Now, the same train number in the timetable may refer to quite different stock, as determined by the car numbers indicated in the waybill. Does that correspond to the same physics? It is here that the true relativity enters the game: the definition of a physical system depends on the mode of its inclusion in some environment that need not be directly related to any physics at all. For humans, their conscious activity is to provide such a reference. In inanimate nature, one is to consider a hierarchy of physical processes that can be unfolded in any particular direction, for the higher layers to determine lower-level physics outlining the essential traits of their dynamics. The notion of a point is thus becoming fuzzier.

Take a trivial illustration: a small physical body moves along a straight line. The body is to disappear in one place and reappear in another. Since, by assumption, there is some motion, the body will certainly occupy these spatial positions in different time moments. Conversely, the moments of departure and arrival are bound to be registered in different spatial points. Nevertheless, we somehow have moral right to measure the distance thus covered (as if the dimensions of a stationary object were concerned) and divide it by the travel time (as if read off from the same stationary clock) to obtain the speed of the body as a measure of motion. For the time being, let us put aside the mass and inner complexity. One way or another, when the theory of relativity is expected to offer purely local picture of space-time, this is no more than an illusion; as a practical idea, any motion is essentially nonlocal since it takes the deliberately different as the same. The problems of quantum theory are even harder: the configuration space is infinitely dimensioned, and there are many way to pass from one configuration to another; by the basic premise, there is no way to observe that displacement.

Still, the quantum analogy allows to, at least metaphorically, visualize motion as occupying several positions at once. Let the state of a physical body's motion be represented by a weighted combination of the initial and final states; an appropriate normalization will ensure the integrity of the system (that is, we are discussing the displacements of the same thing); the way of switching between the coefficients from the pair (1, 0) to the pair (0, 1) depends on the overall character of motion (the chosen scale).

Alternatively, a classical metaphor might come as handy: considering the final size of any physical point, the process of displacement cam be pictured as a smooth flow from one container to another, with some overlap of the old and the new; the separation of the initial and final states is also dependent on the scale selection.

In either approach, the system shows up to be hierarchical: on the lower level, there are the initial and final state on themselves, abstracted from motion; the unity of the two (the state of motion) is achieved on a higher level. There is yet higher level of physical scales (frames of reference) serving to link the former two levels to each other (which cannot be done from within). Once again: the admissible scales are never arbitrary, and they constitute an indispensable layer in the structure of any physical system; this is how nature is made. The selection of a scale is in no way an observer's caprice; we can only choose from the objectively possible in accordance with the character of physical interactions, including the interaction of the physical system with the observer. As it comes to motion in nature, it may be hard to say who observes what: there is interaction of qualitatively different physical systems, which defines a higher-level system, a physical bond. It may sometimes be impossible to split the integral picture of interaction into the interacting systems as such and the process of interaction (represented by a physical system of a certain kind, the carrier of interaction); the structured theory is accurate enough in the inner domain, far from the critical points, physical boundaries (mathematically modeled by singularities, infinitely small or infinitely great values).

On the practical side, the singular regions are not generally accessible. Just because our instrumentation is to eventually be correlated with the size of our biological bodies. Technological progress necessarily expands the range of the achievable scale; however, switching a scale may be quite a challenge. For instance, to discern the structure of the light barrier (thus confirming the impossibility of the exact determination of the speed of light), one may need to reach the speeds within some trifling part of percent (dozens of decimal orders). It is highly likely that the effect could be revealed in much slower movements; but it is not clear where to seek for it. No doubt, indirect measurements are the most powerful method in science; however the risk of stretching the results to a theoretical tradition is much higher than in direct measurement.

One way or another, there is a fundamental fact: the very possibility of motion is related to the nonlocal nature of physical systems, their presence at several places and times at once. Moreover, these particular times and places are merely an expression of coexistence, interdependence, participation in the same process. This implies hierarchy: the discernible on one level is closely coupled on the next. The train as a whole is formed of a number of components (like the cars, the engine, the platforms *etc*.) considered, in some approximation, as an integrity; the character of the junction determines the *inner* space of the train; on a higher level, the train will look like a point (or a region) of a different, *outer* space structured in accordance with the mode of its inclusion in a yet higher-level integrity. To keep this hierarchical construct together, one needs to somehow relate one level to another: they do not exist in separation, as one level is reflected in another. That is, we have all the reasons to describe the structure of the inner space in terms of the outer space, and the other way round, to "embed" the inner space in the outer. The ways of such interconnection may largely vary, but they will never be arbitrary, since they can be represented by the elements of yet another level of the same hierarchy. The constraint of the same value of the speed of light for the inner and outer observers is one of the options; alternatively the inner and outer pictures may be interconnected in a quantum-mechanical manner: macroscopic (higher-level) quantities are thought of as the asymptotic states of inner motion (related to the choice of the basis). In thermodynamics we don't have any outer space at all, and everything physically happens "in the same point"; still, this point is not infinitely small: it has a definite volume, so that (on some intermediate level) the whole thermodynamic system can be split into subsystems represented by a collection of connected volumes. The transition from one mode of description to another depends on the overall character of motion; this is yet another indication of the limited usability of traditional formalism in mechanics, with the premise of precisely measurable coordinates.

Mathematics is indifferent to the physical structure of space. However, the very choice of model makes relativistic physics intrinsically nonlocal. Indeed, the covariance requirement is based on the assumption of the feasibility of global coordinate systems, with as global coordinate transforms. This means virtually implies the treatment of such coordinate systems as pertaining to the inner space of some higher-level physical system (a frame of reference, a global observer, or a god if you wish). On the contrary, for a material point, this coordinate description refers to the outer space, while the inside of the moving body is represented by a flat (1, 3)-dimensional space describing the available choices to move on (the direction and pace of transition to the neighboring point of the outer space). Effectively, this is an inner observer ordering the knowledge of the outer world by the degree of remoteness. Since the incoming data reflect the relativistic restriction on the signal speed, the picture of the world for the inner observer will certainly have a kind of horizon, with know information of the outer world beyond that limit. However, it does not mean that the outer world is also limited in the same manner: logic only forbids discussing too remote events within the current observation scheme. The structure of the inner space as such does not depend on any outer circumstances; this (formally infinite) space exists all at once, in its entirety, with no restrictions on the comparison of spatial regions separated by a distance of any scale. In the same way, the outer space is immediately given to the outer observer, with no need to gradually construct it depending on the succession of events. The reflexive character of this hierarchy is normally introduced by the correspondence principle: the geometry of space-time becomes nearly flat in the vicinity of every point. One level thus gets projected onto another. Still, the nature of the bond is entirely determined by using electromagnetic field as common scale for any other processes. In general, the correspondence may be less trivial, as the inner space of a material point can contain degrees of freedom that are absent in the outer world, and conversely, some outer coordinates can be statistically degenerate in the inner space.

With any choice of a scale, its structure is different from that of formal mathematical spaces by the presence of finite discrimination thresholds. A physical point is not mere number; it is not infinitely small, but rather spans over some spatial zone within which the observer (the other components of the same physical system) could not distinguish one thing from another. This has nothing to do with the discreteness of the container space; all we can assert is that very close points will merge on the chosen scale, behaving like a single material point in respect to physical interactions essential for the system as a whole. In principle, system dynamics can lead to the spatial separation of the formerly mingled material points (with their transition from one zone to another), with the effect of the birth of several equally elementary "particles". The specific features of the organization of the physical space (including zone sizes and the degree of their separation) are related to global symmetries. Thus, the presence of a limitation on the admissible values of a physical quantity (a boundary) is to produce lattice-like zone structures (similar to musical scales[12]). That is, the finite speed range and the existence of the relativistic barrier will produce a lattice space on the global scale; the same holds for spaces containing all kinds of geometrical singularities (similar to an event horizon). No need to say that any physical symmetries cannot be but approximate, so that apparent boundaries will only show up for a very remote observer.

An analogy with atoms (or any other compound quantum systems) would be quite appropriate here. For the motion of free particles, we observe continuous spectra; with an increase of the coupling strength, specific non-monotonicity will be superimposed on that background; finally, the formation of bound states will manifest a number of narrow spectral lines, which, however, get broadened due to the virtual exchange with the spectral continuum. Similarly, for each physical system, the geometry of space-time arises in the interactions of some distinct parts: for weak interdependence, the physical space can be satisfactorily represented by mathematical spaces; closer coupling leads to geometrical and topological peculiarities, though no borders can be absolutely sharp.

Physical bodies are not like mathematical points; their inner organization will influence the outer motion. To move a material body from one place to another is not so easy, and it can never be pictured as a momentary jump. In the hierarchical model, the outer position of a physical body implies unfolding its inner hierarchy starting from some initial node. To displace the such a structured point, one needs, first, to fold the inner hierarchy, and then unfold it in a different manner, from another vertex: kinematically, any motion is a special case of hierarchy conversion. The more developed the inner structure, the higher the inertia of motion; in mechanics the overall measure of this inertance is known as mass. The interaction of massive bodies means their inclusion in a higher-order integrity; since this implies additional effort of folding and unfolding, interaction will contribute to the total mass. However, such coupling may require a transition to a different physical scale and a rearrangement of the inner and outer spaces; that is why the mass of a compound system need not be always greater than the formal mathematical sum of the incident masses: the disjoint and compound systems exist on different levels of the physical hierarchy.

[12] L. V. Avdeev and P. B. Ivanov, "A Mathematical Model of Scale Perception", *Journal of Moscow Physical Society*, **3**, 331–353 (1993).

Joining separate physical system in an encompassing system normally means introduction of new scales, both in space and time. Thus, when we are to determine the distance between the instruments of a human size separated by hundreds, thousand, or even millions of miles, the size of the resulting system is far beyond the original scales, and a special procedure is required to switch to the new dimensions. As long as we cannot surpass the common-life magnitudes, the structure of the higher-level scale will remain merely a working hypothesis developed upon some reasonable (in our opinion) conceptual grounds. In particular, we cannot observe the outer space in its entirety, as an outer observer would; we cannot go beyond the horizon imposed by the finite interaction propagation speed. Similarly, the necessity of coordinating events separated by times much longer that their local span, we have to base our conclusions on some hypothetical considerations, which may be far from the real structure of the compound system. The problems of that kind are inevitable; but they are not the hardest challenge to face. There is a principal moment: how do we paste two independent instances of space-time together, in the common space-time of the compound? Thus to combine the mechanical motion of two material points, we are to somehow distribute the original eight (outer) coordinates (six spatial and two time-like) between the inner and outer degrees of freedom of the new system. In non-relativistic mechanics, such coherent motion is normally described by the coordinates of the center of mass, while the reduced spatial coordinates and time refer to the inner motion (provided that the inner and outer scales are qualitatively different). In relativistic mechanics, the notion of the center of mass is ill-definable, which is basically related to the conceptual confusion: the speed of light is said to be the same for both the inner and outer observers, which is a logical fallacy, since each level of hierarchy requires a scale of its own, and one cannot identify the quantities of different nature. Physically, inner movements should be much faster than the characteristic speeds of outer motion; that is, from far away, why we only see an averaged picture, a massive point. To keep the notion of a material point for faster inner motion, comparable to outer displacements, the observer must be placed beyond the scope of the both; that is, we need a scale much rougher than the inner scales. Otherwise, instead of a point, we will observe something distributed in the outer space (and in outer time); relativistic kinematics does not pertain to the systems like that.

As a mere formality, we are free to link anything to anything at all. This invokes yet another mathematical abstraction, the notion of a set. Still, physics is basically a science about interactions. Physical system do not result from a formal comparison of different movements; on the contrary, the feasibility of adding things up is related to the real hierarchy of the world, which contains both the level of the union and the level of its components. The occurrence of various “emergent” properties in abstract system is sheer illusion. Yes, such combination are theoretically possible; but they have nothing to do with physics: at best, this is a different science, with its own spatial and temporal notions.

It’s high time for a brief summary. There is no “true” geometry of space-time, and no way to meaningfully introduce it in physical theory. There are physical system of many kinds, and their geometry (and topology) is determined by the nature of inner interactions and the mode of inclusion to some production environment (a frame of reference), Inner and outer motion develop in different scales; there are objectively formed (natural) scales. Any formal derivation is only valid on the condition of clear separation of these levels, far from the transitional areas. In particular, the mechanics of a relativistic point (as well as its superstructure, the general theory of relativity) is only applicable in smooth (non-singular) motion, when the system objectively behaves as a number of points placed and evolving in a common space-time. The universality of such a picture is deceptive, and future discoveries are bound to significantly extend the range of available paradigms.

CONTENTS

On Virtuality 1
Remarks on F. J. Tipler 3
The Logic of the Paradox 4
Quantum Nonlocality, Stellar Evolution and the Integrity of the Universe 5
EPR Experiment and Complementary Paradigms in Physics 6
Time *vs*. Interval 11
Black Holy Logic 13
Observers, Time, and Velocity Measurements 18
Among the Wise and Crazy 23
Global Relativity and Relative Locality 29
Energy and Information 38
Phenomenology of Space and Time 40
Dazzling Ideas 47
Nonlinear Kinematics 50
A Bright Thought of the Dark Matter 51
On Inertial Rotation 53
Heads Properly Placed 57
Equilibrium in Manifolds 62
Relativistic Illusion 68
Hierarchical Observations 71
Deceptive Physics 78