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QUANTUM COSMOLOGY, POSSIBLE WORLDS, AND MODAL ACTUALISM

1. INTRODUCTION

The growth of modern science resulted in a radically new cognitive approach to many problems of classical philosophy. In the context of contemporary theoretical physics, if only one avoids easy apologetic, it is no longer possible to defend this version of epistemological empiricism that was defended half a century ago. Whereas in the 1930's the traditional distinction between theoretical and observational terms was called into question, due to its arbitrary nature, in the 1980's the basic philosophical opposition between material and immaterial *(resp.* between physical and mathematical) objects seems arbitrary since the very notion of matter appears nothing but a terminological relic of the bygone epoch. Already at the beginning of our century in his paper Alfred N. Whitehead argued that the concept of the so-called material world, basic for the 19th century materialism and mechanism, remains a result of metaphysical intercalation irrelevant for modern science in which the basic role is played by mathematical formulae which we consider in relation to empirical evidence (Whitehead 1906). This opinion is confirmed by contemporary scientists who use the term „matter" merely for pragmatic reasons to avoid more precise and more complicated descriptions in the terms of mass, energy and momentum distribution. The „matter" of such pragmatic descriptions has, however, nothing in common with the classically understood matter regarded as a basic philosophical category in many philosophical currents.

New physical theories bring new ontological of primary importance. Current philosophical debates about the ontology of the so-called possible worlds belong to such a set of problems. In this paper I shall present the interpretation of the concept of possibility underlying new theories in quantum cosmology, and argue that these theories seem to confirm the standpoint of modal actualism adopted, among other authors, by Robert C. Stalnaker and, in a different version, by Alvin Plantinga.

2. DEMATERIALISATION OF MATTER IN CONTEMPORARY PHYSICS

Already in Newton's physics the notion of mass, intuitively closest to the philosophical concept of matter, has been reduced to a mere parameter in the formula $F=ma$ and deprived of its common-sense content that was adopted by the Enlightenment materialists as the basis for their philosophy. The irony of the situation consisted in the fact that the 18th century authors referred to scientific theories to confirm their philosophy at the time when the intuitive concept of matter was already eliminated from these theories. If today we would like to preserve the meaning ascribed to the term „matter" by LaMettrie, Diderot, Engels and Lenin, we could call material neither elementary particles nor physical fields since they scarcely display properties that were regarded by these authors as characteristic of all material objects.

The Planck-Einstein revolution in physics resulted in total abandonment of the common-sense concept of matter. As Werner Heisenberg emphasized during the Athens meeting in 1964, the fundamental units of so-called matter „are not in fact physical objects in the ordinary sense; they are forms, ideas which can be expressed unambiguously only in mathematical language" [Heisenberg 1966, p. 37], Certainly, the reverence for the linguistic tradition of the past may be expressed in applying the adjective „material" to quanta of a physical vacuum and to new types of physical fields. One should notice, however, the deep changes of semantic content combined with such an interpretive procedure. The philosophical significance of these changes is often ignored, and — as Chris I. Isham rightly stresses — it is usually not noticed that in the so-called theories of everything (TOE) we can satisfactorily describe the „material" substratum of the universe in terms of interacting quantum fields [Isham 1988, p. 402], Such a practice demonstrates that there exit deeper ontological structures which may appear useful for determining the substantial content of the fuzzy concept of matter.

In the new conceptual approach of contemporary theoretical physics, the notion of physical objects, fields or interactions plays the role played in the past by the concept of material substratum. Again, however, these new terminological conventions express merely research practice of the present epoch. In this very practice we adopt the term „physical" as a shorthand pragmatic device instead of a longer formula „the one accepted in the paradigm of contemporary physics". Consequently, what the precise meaning of „physical" is, depends on the adopted philosophy of physics as well as on epistemological distinctions between physics and mathematics. R. Hagedorn was by no means alone in argueing that at the subatomic level the traditional distinction between physical and mathematical objects may turn out pointless, since the properties of the objects of this level violate basic epistemological distinctions approved in the past. This suggestion converges with opinions of the authors as different as W. Orman van Quine and Kurt Godel. The former critically assesses the present terminological conventions when he admits that elementary particles are called material „only by courtesy” and contends that physics is continuous with mathematics since atoms and particles have the same epistemological status as sets and classes. [Quine 1982, p. 148f], The latter is well-known for his Platonic declarations in which he regarded the traditional opposition between logical and physical objects as merely a prejudice of our times. [Godel 1964, p. 220].

Setting aside the old controversy about metamathematical Platonism, I would like to point out now that the traditional opposition developed in classical ontology between pluralism and monism loses its former significance because the very distinction between material and immaterial elements appears either pointless or dependent on terminological conventions that remain remote to the research practice of the natural sciences. In the cognitive framework underlying the present scientific practice, mathematically described symmetries, universal laws of nature, and uninstantiated potentials for the growth of physical systems seems much more relevant that the aspects that attracted traditionally the attention of philosophers. New scientific results, as R. H. Schlagel expressed [Schlagel 1984, p. 373], justify the conclusion that the human condition is certainly not the Humean condition and its essence cannot be described in empirical categories. Common-sense philosophy of empiricism that in the 18th century seemed to express critical thinking can be no longer maintained today when scientific theories systematically go beyond our common-sense intuitions.

The adage „matter has been dematerialised in quantum physics” expresses the deep transformations that took place in physics after the Einstein-Planck revolution. After these transformations, it seems a question of convention whether or not we apply the term „physical” to, for instance, a quantum vacuum in which no physical particles exist. An alternative possibility would be to interpret this vacuum in philosophical categories of the possible worlds regarding the quantum vacuum as an object endowed with possibilities of generating certain physical states of affairs. To develop the latter interpretation within the framework of modal actualism, I will refer to new physical theories of
the creation of the universe from the vacuum fluctuations. Already classical versions of such theories were proposed in recent years by J. B. Hartle and S. Hawking [1983], R. Brout, F. Englert and E. Gunzig [1978], R. P. Tryon [1973], A. Vilenkin [1982] and many other authors. As a result of their new approach, the basic metaphysical notion of the creation from nothingness was introduced into scientific theories and disclosed new interpretive perspectives in attacking the fundamental problem of

ontology.

In an optimistic appraisal of these new theories John Gribbin argues that the new physics of creation leaves no place for the traditional metaphysics of creation since new cosmological models ultimately explain how the Universe *created itself*, emerging from nothingness at a certain moment t_0; and as a result the metaphysicians „are out of job" [Gribbin 1986, p. 392] An opposite view is defended by C. J. Isham who contends that there are many intriguing problems related to creation and evolution of the universe to which modern theoretical physics provides no decisive solutions [Isham 1988, p. 405]. Sharing the latter opinion, I will now focus upon these aspects of the theory of vacuum fluctuations, proposed in quantum cosmology, that seem to contribute to our better understanding of basic philosophical issues.

A vacuum in quantum electrodynamics is understood as the lowest energy state of a field in which no physical particles exist. It should not be identified with philosophically conceived nothingness because the vacuum possesses a rich mathematical structure that can be described by means of the formalism of quantum field theory. The absence of physical particles in the vacuum is described in this formalism by the formula $\hat{a}\Phi_o = 0$, where $\hat{a}$ is an annihilation operator and Φ is the state vector. Despite the absence of particles, physical fields do not disappear, and their properties can still be characterised in the abstract language of mathematics. The state vector Φ characterising an arrangement of n particles in states $i = 1,2,...$ can be presented as the result of the action of n creation operators on the state vector of the vacuum. Designating these operators by $\hat{a}_i$, we can describe any physical state of the investigated system as a function of the state vector of the vacuum:

$$\Phi = \hat{a}_1\ \hat{a}_2, ..., \hat{a}_n\ \Phi_o.$$

The indicated possibility manifests that in an evolving physical system any particular state described by the vector Φ can be regarded as the actualisation of potentialities that are contained in the physical vacuum. From the philosophical point of view, this vacuum may be conceived as a unique field of potentialities of which only some possibilities are exemplified (=instantiated) in the physical processes that occur at the present stage of cosmic evolution.

Philosophical reflection upon 20 billion years of cosmic expansion guards against interpretive anthropomorphisms in which the narrow scope of experience accessible for our species was supposed to be the main criterion of truth. It is well-known that the perceptive capacities of human beings are a product of accidental conditions of the phylogenetic growth. As the result of these conditions, the human eye reacts to wavelengths in the band 4000-8000 angstroms and our hearing to sounds with a frequency of 16—20000 Hz. Any attempt to build empiricist philosophy restricted to this domain of experience would result in anthropomorphic generalisations in which one ignores the abundant realm of possibilities disclosed by theoretical physics.

When investigating these possibilities which took place in the early universe, 20 billion years ago, we discover explanatory patterns that not only transgress the domain of experience accessible to our species but also go beyond our intuitive schemes and can be described only in abstract formulae of mathematics. The creation of physical particles in a vacuum may be regarded as an example of such a philosophically intriguing process. In this process, in accordance with Heisenberg's uncertainty principle, virtual quanta are created in the vacuum for a short period of time without violating the principle of energy conservation. These quanta may appear in the form of pairs consisting of virtual particles and anti-particles which mutually annihilate a short time later. In various physical theories, diverse mechanisms are described that are to derive necessary energy from space-time curvature in order to transform the quanta of a vacuum into real physical particles. In the already classical variant of this process interpreted by Englert, Brout and Gunzig, the universe emerges from the vacuum as a result of symmetry breaking. No physical conservation law is violated in this process because the energy of the newly created particles is balanced by the negative energy of gravitational field generated by these particles.

The physicists who rightly contend that four dimensional empty space cannot be regarded as a counterpart of metaphysical nothingness undertook more ambitious attempts to construct better physical models of the creation *ex nihilo.* A most interesting philosophically solution seems to be found in models worked out by Alexander Vilenkin as well as by S. Hawking and J. Hartle. In Vilenkin's model, proposed in 1983, there is no pre-existing space [Vilenkin 1983], The creation of space-time results from the quantum mechanical effect of the so-called tunneling. Before this effect occurs, there are no physical particles, no matter, no space and time; using the language of mathematics one could compare this state with the empty set of set theory. This mathematical emptiness is, however, subject to laws of quantum cosmology as well as to basic principles of logic. These principles and laws are valid when no physical structures exist. Their validity defines the domain of the *possible evolution of the universe.* Independent of conventions there remains the very fact that we can describe mathematically the mechanism of emergence of the existing cosmic structures from the state of physical nothingness in which only rational abstract principles may be thought of as real. Philosophical content of this fact seems scarcely consonant with any version of empiricist ontology whereas it provides new premises to develop these versions of modal actualism that were earlier proposed by Plantinga and Stalnaker.

3. PHYSICAL VACUUM AND PHILOSOPHICAL MODAL1SM

In its process of long development, philosophical interpretation of nature was focused upon actual observable particulars. The meaning of the „actual" evolved when, in the prevailing *Weltanschauung*, the empyrean and the souls of the world were replaced by material particles and the laws of motion. One kept unchanged, however, the cognitive stance in which the domain of everyday experience was regarded satisfactory to discover adequate philosophical principles that were supposed to apply universally. There were many domains in which these principles appeared evidently unsatisfactory to explain the available data. Well-known issues concerning the ontic status of counterfactuals and modal categories provide a paradigmatic example of such a domain. Attempts to overcome narrow empiricism in debates on these issues were criticised because of the alleged violating of Ockham principle what resulted in the overpopulated ontology of possible worlds and vague metaphysics.

Such a critique seems justified merely when aimed at the extreme version of modal realism defended by David Lewis in his variant of apparently Meinongian ontology, according to which all possibilities are actualised in mutually isolated countless worlds [Lewis II 1986, p. 2]. In general, however, Ockham's razor was not to be used to surmount overpopulation in ontology but to provide explanations that are both economical and satisfactory. One can hardly regard satisfactory this nominalist approach to modal possibility in which possible worlds are nothing but linguistic state descriptions. Such a theory cannot be meaningfully applied to the set of possibilities described by mathematical formalism of the physical vacuum. The amazing property of the description reveals in the fact that possibilities „encoded" in the original state of the evolving universe were instantiated in later stages of cosmic evolution. Nominalist philosophy neither explains this fact nor answers a more general question why mathematics can be effectively used in describing natural processes and predicting future physical events. To regard the mathematical formulae used in physical description of the vacuum as merely *faęon de parler* would be about as adequate as an attempt to express the beauty of a Beethoven symphony in terms of physical frictions. The *faęon,* though extravagant, is tolerable but it takes no account of the essence.

The position of modal conceptualism does not seem much better in this respect, insofar as the conceptualist ascribes the basic role to human mind in explaining the status of the these possibilities that were never exemplified in observable phenomena. Nicholas Rescher's claim that the existence of possible worlds different than the actual world is rooted in human intellectual processes of supposing and hypothesizing [Resher 1979, p. 169] does not allow consistent distinguishing between purely fictional products of human fantasy on the one hand and actual but unexemplified possibilities on the other. In the stance of modal conceptualism one simply ignores ontological consequences of the fact that the mean value of every physical quantity can be presented in the form of the mean value of the operator in the state of the physical vacuum. If the significance of this fact is acknowledged, one must recognise two basic modes of existence: 1) the existence of concrete objects (=particulars); for example in observable particulars; 2) the existence of abstract objects (=universals, properties) that can, but need not be exemplified in particulars.

We can easily imagine a different scenario of cosmic evolution; a scenario in which the universe would never enter into the stellar era, the Solar System would never develop and philosophers (if any) would never refer to their beloved examples with Phosphorus and Hesperus. The very fact that in our universe such examples are possible depends on the abstract laws of cosmic evolution that were „encoded” in the set of possibilities which already existed in the quantum vacuum. By all means, it existed in a different mode than stones, flowers and philosophers exist at the present epoch, because observable particulars exemplify the existence of the latter class of objects but not of the former. This obvious difference does not allow questioning the real existence of objects that are uninstantiated in particular phenomena; it only shows the peril of unsubstantiated anthropomorphic generalisations in which categories dependent on biology of human species are regarded as supreme cognitive criteria.

When commenting on the role of the quantum vacuum in the new physics, Heinz R. Pagels comments:

> Instead of ’Nature abhors a vacuum’ the view of the new physics suggests, The vacuum is all of physics. ’Everything that ever existed or can exist is already potentially there [...] All of physics — everything we hope to know — is waiting in the vacuum to be discovered. [Pagels 1983, p. 2441].

The statement „everything that [...] can exist is already potentially there” expresses the truth of primary importance. It ascribes real existence to abstractly understood possibilities that can be exemplified in future physical processes. This mode of existence can be reduced neither to linguistic regularities nor to mental processes. Even if a tragic nuclear destruction had not allowed actualisation of certain possibilities of cosmic evolution (and, as a result, these possibilities had never been exemplified in observable physical processes) they would be, nonetheless, as real as all other possibilities determining the nature of cosmic evolution.

This physical-theoretical recognition of possibilist categories remains a characteristic not only of the new theories of quantum cosmology. Already in the 1930's in his interpretation of quantum mechanics, Werner Heisenberg argued that in quantum systems the investigated properties are real but only as potentialities. They are not „actualised" until the process of measurement. Heisenberg's scientific opponent, David Bohm, in spite of the evident defeat of his own theory of hidden variables in physics, adopts philosophical views convergent with the opinion of Heisenberg. According to Bohm, the so-called „explicate order", observable on the level of actual ordinary phenomena, is nothing but a manifestation of the so-called „implicate order" consisting of a series of possible ontologies [Bohm, 1980]. The well-known deficiencies of Bohm's interpretation in quantum mechanics influenced the underestimation of his philosophical views. Many authors who tried to overcome prejudices and to do justice to Bohm, rejected his conception of hidden variables but found his philosophy of the implicate order very attractive [cf. Russell 1985],

Setting aside the assessment of Bohm's controversial philosophy, one has to notice that the possibilist categories play evidently the key role in quantum physics. Both when dealing with such basic terms as the Φ function of probabilities of distribution and when defining the implicit assumptions of Hawking-Hartle approach to the quantum creation of the universe, we find that in physics the domain of the actual existence is defined by the adopted mathematical formulae, whereas physical exemplifications constitute only a proper subset in the previously determined domain of possible exemplifications. The very fact of introducing certain mathematical expressions imposes (at their standard interpretation) important restrictions on the domain of possibilities that can be instantiated in physical processes. The adopted mathematical formalism which determines the range of the possible growth appears more important than the nature of physical substratum of the actual properties of physical quanta.

It remains a subject of controversy whether, as Hawking contends, all actual physical conditions can be determined on the basis of mathematical formalism. If Hawking is right on this point, it would be aesthetically pleasant but ontologicallv useless. The fact of primary significance for ontoloev is that

function Φ, adopted by Hawking and Hartle as a wave function of the universe, provides again new support for the standpoint of modal actualism. C. J. Isham describes the philosophical significance of this function:

> ...the entire history of the quantum gravity system is coded into the *single* function Φ, and we no longer talk about paths in the state space. Instead [...] for each pair (c, f) Φ (c, f) should be understood as giving the probability of finding a particular physical distribution $(c, f)_{Phys}$ of curvature/gravity and matter at the internal time determined by the values of c and f. [...] The initial

> space from which the universe „emerged" can be defined to be that part of the boundary of the four-dimensional space which is *not* part of the (later) three-surface. But this is the empty set, which gives a precise mathematical definition of the concept of „nothing"! [Isham 1988, pp. 396, 401].

In similar descriptions one systematically violates well-ordered principles that determined distinctions between the actual and the possible on the one hand and being and nothingness on the other. These violations need not necessarily result in a conceptual mess. Firstly, one has to notice that in similar comments the „nothingness" described by physicists should not be identified with philosophical nonbeing. To the so-called physical nothingness we may apply principles of mathematics. Consequently, its status seems similar to the status of philosophical logos rather than to nonbeing. Secondly, the menace of conceptual chaos disappears if real existence is granted not only to actual but also to possible objects. Such a decision requires ontological commitment in which abstract possibilities constitute the primordial ontic level and their concrete exemplifications constitute the subsequent observable reality of everyday experience. It depends on personal preferences whether this primordial level shall be characterised in terms of universals, properties or states of affairs. Different terminological predilections can result in identical explanatory power if only one acknowledges the real existence of universals which at a given period are uninstantiated but can be instantiated in different circumstances.

Psychological objections against the idea of uninstantiated universals result from the limits imposed on human creative imagination. The need for its acceptance becomes particularly manifest when we go beyond the domain of everyday experience and examine processes essentially different from the well-known mundane phenomena. For this reason, the analysis of cosmic evolution provided by quantum cosmology seems particularly useful in discovering ontic structures free of contamination by common sense anthropomorphisms. This very analysis reveals that in the hadron or lepton stage of cosmic evolution, when there existed no instantiations of planetary or galactic structures, no carbon-based animate organism could have arisen and no psychic processes possessed exemplifications. As the so-called Weak Anthropic Principle suggests, to explain the appearance of the latter we must refer to the laws of cosmic evolution that restricted physical processes in the early universe. In the initial cosmic stage characterised by high densities and temperatures, no universals determining the growth of biological organisms were instantiated. They existed, however, in an unistantiated form as elements of more fundamental nomic structure that displayed its reality in the expanding early universe.

4. CONCLUSIONS

When expounding his theory of counterfactuals, David Lewis asserts: „possible worlds are widely regarded with suspicion... I shall argue, however, that the suspicions are not well justified". [Lewis 1986/1, p. 84] Lewis himself, however, contributed to the growth of suspicions when in his theory of so-called modal realism he presented a vision of countless separated worlds and in their portrayal introduced easy-going descriptions unrelated to any scientific data. In Lewis' cavalier ontology the possible

> ...worlds are something like remote planets but they are not remote. Neither are they nearby. [...] [T]hey are not at any temporal distance at all from now. They are isolated; there are no spatiotemporal relations at all between things that belong to different worlds. Nor does antyhing that happens at one world cause anything to happen at another. [Lewis 1986/11, p. 2],

Such a vision of causally disconnected universes remains closer to science fiction than to physical theories. Perhaps one could treat it as an ontological counterpart of Everett's many-worlds interpretation in quantum mechanics. This interpretation, however, could scarcely be conceived of as a heuristically valuable theory in contemporary physics. Lewis' strong metaphysics deprived of any physical basis inspires opposition against the Platonic stance in possible worlds theories. Quite a separate problem remains whether or not Lewis' „modal realism" may be regarded as a version of Platonism. Plantinga seems right when he notices Ockham's influence upon Lewis' conception of actualised universals. [Plantinga 1987, p. 189], Ockham's razor and scientific data are, however, in this conception systematically ignored, what certainly influences these critical assessments of the possible worlds theories that are developed within the framework of nominalism.

To a certain extent the opposition against the standpoint of modal actualism results from ambiguous terminology. In the linguistic practice of various philosophical traditions, the meaning ascribed to terms „actual", „actualism", „existence", „merely possible" is so different that Kit Fine in his critique of Plantinga's actualism credits the author of *The Nature of Necessity* with opinions the latter never held [Plantinga 1985, p. 330]. In philosophical comments of natural scientists, very often the expression „possible" is used to denote what Plantinga and Stalnaker call „existing but uninstantiated"; consistently, the „actual" is sometimes opposed to the „possible" and not conceived of as an abstract structure underlying observable particulars. There also were Scholastics who in their discussions of the *mere possibilia* followed terminological conventions different than the ones adopted by Plantinga. In their approach, the „mere possible" did not denote nonexistent possibilities but only uninstantiated abstract possibilities. In spite of terminological differences, the content of their arguments remains consistent with the arguments of modal actualists.

Another type of disagreement may result from various understandings of the term „existence" in different philosophical traditions. There are many authors, especially among representatives of phenomenology, who follow Roman Ingarden in distinguishing various modes of existence. In the language of their philosophy, one must acknowledge indexed modes of existence; consistently what Plantinga calls „actual existence" (= *actual existence j)* may in their terminoloev differ from their understanding of the ..actual existence"
(= *actual existence*$_k$, k $\neq$ i).

Plantinga himselt acknowledges the the adopted terminology to be „unfortunate" and admits that „actualism should really be called ‘existentialism’. By now, however, it is too late; ‘actualism’ is already entrenched” [Plantinga 1985, p. 92], Setting aside these terminological infelicities, we have to admit that the distinction basic for modal actualism, the one between instantiation and existence, remains important when we try to interpret ontologically the role of mathematical physics in describing events that have no exemplifications in our actual world. In the terminology of modal actualism, the essence of this stance may be expressed in asserting that the proposition „there are no things that do not exist” is necessarily true [Plantinga, 1985, p. 314], Such a formula evidently differs from common language expressions in which we assert nonexistence of certain objects. In the actualist mode of expression such utterances should be reformulated to inform that certain possibilities (that actually exist) are unexemplified. If in the growth of human technology the drama of Hiroshima, Nagasaki and Chernobyl had never taken place, the consequences of the impact of radioactive radiation on human organism would remain unexemplified events in the 1980’s or, in even more optimistic perspective, could remain unexemplified forever. The absence of particular instantiations in the set of observable physical phenomena does not imply, nonetheless, nonexistence of such an impact. The impact exists as an abstract possibility and is regarded actual because it actually exists as an abstract structure underlying the observable world of exemplified particulars.

New physical theories may play an important role in overcoming the common sense conceptual restrictions. The mathematical description of the early stages of cosmic evolution reveals the differences between the actual existence of abstract possibilities and the actual existence of their concrete instantiations (= exemplifications). The maximal set of states of affairs that is exemplified in the observable physical phenomena constitutes the so-called actual world. The set of possibilities that exist without being instantiated is both real and physically necessary to explain processes that occur in our actual world. To predict the future of cosmic expansion we must know not only the actual amount of matter but also abstract relationships determining the conditions of possible collapse. Both of them have real impact on the future of cosmic evolution; both of them actually exist, though in a different manner.

All signalled distinctions are important to avoid unsubstantiated polemics in the domain where messy terminology could easily result in pointless controversies. Terminological clarifications cannot, however, contribute to overcoming psychological objections against the very notion of an existing abstract objects bereft of concrete exemplifications. To overcome these difficulties we must liberate ourselves from empiricist intuitions which allow only the existence of particulars. When we recognise the existence of actual abstract objects, it does not matter whether we will call them properties, sets or states of affairs, we commit to a version of Platonism in which explanatory puzzles disappear but intuitive objections arise. The latter type of objections seems to be a permanent constituent in the growth of human knowledge. Its earlier counterparts emerged when the movability of the Earth was discussed, action at a distance was proposed instead of a physical contact, the atom indivisible *ex* *definitione* appeared divisible in fact. The growth of science brought about important revisions in the ordered explanatory schemes of the past. As a result of these revisions, many intuitively intelligible concepts disappeared from scientific vocabulary sharing the fate of crystalline heavens and perfect spheres. Their place was taken over by forces and fields, potentials and waves of probability. The terms „real dispositions", „potential", „capability", „propensity" are used by contemporary critics of Hume to describe „the dispositional properties" of physical objects [Thompson 1988, p. 68], Though all these terms remain psychologically remote to our basic intuitions, their semantic equivalents influenced the radical changes in our understanding of nature and contributed to dramatic technological variations. To solve effectively the amazing puzzles of world structure, one has to go beyond intuitively obvious prejudices and adopt new concepts that are both psychologically counter-intuitive and interpretatively necessary.

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