THE UNITY OF SCIENTIFIC KNOWLEDGE IN THE FRAMEWORK OF A TYPOLOGICAL APPROACH OF THEORIES

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ABSTRACT: The paper proposes a typology of the scientific theories based on the modality of mathematizing (relying on the kind of mathematics which participates to the theory edification and the level of mathematical organizing of the theoretical frame). This gives us, like the classification of the geometries from the famous "Erlagen Program" initiated by Felix Klein, an internal principle for the connection of the different forms or levels of the theorizing, a constructive basis for the understanding of the complex structural nets of the mature scientific disciplines.

Keywords: axiomatization of theories, epistemological structuralism, rationality of science.

In the present work we intend to formulate a hypothesis on the epistemological status of theories based on the concept of *type of a scientific theory*. In the logic and methodology of science there are a lot of theory typologies. Thus, one speaks of phenomenological, causal-deterministic, statistical, local, global, "with hidden parameters" and many other theories. These types of theories are determined, in different context of analysis, mathematical, epistemological, methodological, a.o. We shall try to build up (in a schematic an idealized way, of course) a comprehensive typology of the theories formulated within the framework of mathematical sciences or of other disciplines having reached a high degree of theoretical development, starting from a group of interconnected parameters. When examining them, we shall insist mostly on the part played by the mathematization -seen as a principle of theoretical and methodological unity of scientific knowledge forms.

In the current philosophy of science there are several points of view similar to such a typological outlook on the methodological status of theories. Thus, commenting on T.S. Kuhn's thesis on incommensurability, David Bohm considered that

> each theory is a whole in itself, whose analysis in disjunctive components is not at all relevant, (...) because all the terms of such a theory can have their own signification and their own factuality and truth criteria only in the total context provided by this theory (D. Bohm, 1974, 375).

The changing of theories brings about new types of explanation, new testing modalities and criteria, new forms in which scientific results are applied etc. In the same sense,

J. Bub considers that "each theoretical change introduces new criteria of factuality and truth" (J. Bub, 1974, 408).

Such an extreme conclusion ("epistemological solipsism") can be avoided if we take as a unit of reference not the theory (considered individually), but a superior kind of entity, namely the *type of a theory*, a construct to which a (paradigmatically determined) class of theories corresponds extensively.

The general thesis of the approach put forward is the following: a certain level of theory mathematization (or of the signification of "mathematization") finds its correspondent in a certain epistemological and methodological status of theories -a specific modality of determining their object, some criteria of physical reality, specific standards and exigencies of completeness, a kind of explanation and prediction as well as a certain modality of justifying theories; sometimes one speaks also of a logical structure specific to different types of theories. The type of one theory is also related to a characteristic dynamics of the theory, to a distinct way of the evolution of knowledge and -at a higher level- to characteristic objectives and standards of rationality.

The question, what does the mathematization of science mean, does not have a unique and stable answer, independent from the level of development of a scientific discipline or from the peculiarities of knowledge at its different levels. Taking up the evolution of physics as the basis for analysis, we can discern several *stages* in the mathematization of science, each stage being characterized by a certain role played by mathematics in the construction and systematization of knowledge. This is why we are in a position to speak of the existence of some distinct signification of the "mathematization" of knowledge.

In order to obtain a more rigorous formulation of the internal connexion between the type of theorization and the mathematization of science we can use the ideas of C.-F. von Weizsäcker on the mathematical forms of physical laws. In his work, *Aufbau der Physik*, von Weizsäcker distinguishes four mathematical forms in which a natural law can be formulated: (a) a family of functions; (b) a differential equation; (c) an extremal principle; (d) a symmetry group. Between all this forms there is a strong mathematical correlation:

> the solutions of differential equations are families of functions; for each family of functions, one can construct a differential equation of which the set of solutions are those functions; an extremal principle implies differential equations as their Euler-equations; the converse is not in general possible -only some classes of differential equations belong to an extremal principle; a differential equation (and, if exists, its corresponding extremal principle) is in general invariant with respect to a symmetry group, mostly a Lie-Group; inverselly, a group generates on his homogeneous domain family of functions which constitute the group representations (V. Weizsäcker, 1985, 242).

The above mentioned order of mathematical forms of physical laws corresponds in general with the historical manner in which the hypotheses and physical theories are constructed, more exactly, with the main types of scientific theorizing. The classification of von Weizsäcker offers us an effective criterion for a typology of scientific theories. By a sort of "rational generalization" of this criterion we formulate the following typology of scientific theories.

1. The morphological (instrumental) theory

The first modality of mathematizing a scientific discipline has its model in the ancient *formal* (or mathematical) *astronomy*. What is subjected to (global) mathematization at this stage, is its "empirical" part. The methodological principle of formal astronomy -"to save phenomena"- indicated the following signification of astronomy as a science: it represents a purely mathematical discipline which has as its fundamental objective the imagining of some geometrical combinations which should make possible the correct computation of observation data ("appearances"), without conferring a physical significance upon these mathematical combinations. Mathematics is applied in this science to the elements of experience, to the correlation of celestial "phenomena". In this type of astronomy, the hypothesis has the meaning of a mathematical formula proposed to render, in a simple manner, relations between observable phenomena. "The laws of the planets -Sergescu pointed out- are not necessary from a mathematical point of view; they are a physical fact which we note and translate into formulas." (Sergescu, 1928, 138). Mathematical hypotheses were not doubled by models of the *subjacent* behaviour of the object whose manifestations, within the framework of experience, should be considered (and explained) to be 'phenomena'.

This type of science mathematization finds a correspondent in a certain methodological status of theories and also in a certain epistemological outlook on their values and cognitive role. The methodological difficulty of this type of theories has been revealed by Proclos (to whom we owe also the most exact structural description of ancient "hypothetico-deductive" astronomy) in the following manner: "From false hypotheses one can draw a true consequence, and the concordance of this consequence with phenomena is not sufficient proof of the truth of its hypotheses." (R. Blanché, 1969). In other words, experience does not enable us to decide, in this science, the truth quality of the premises, that is, the astronomical hypotheses. As regards the cognitive significance of different astronomical and cosmological systems, we read the following in Osiander's (largely commented) preface to *De Revolutionibus Orbium Celestium* by Copernicus:

> The task of astronomy is, first, to choose by an ingenious and minute description of the celestial movements; second, to look for their causes; to imagine and to invent certain hypotheses in such a way as by their admission and, in conformity with the principles of geometry, these movements should be exactly 'calculated for both the future and the past; (...) and it is not necessary for these hypotheses to be true, not even verisimilar; one thing is sufficient, namely that they lend themselves to a calculation which should be in agreement with the observations. (R. Blanché, 1969).

This instrumentalist outlook on "the systems of the world" is characteristic of a mathematical discipline which has been mathematized at an empirical level and in which the dominant style of problem conceptualization is the global one. The functions of theories will also have a well-determined significance in the sense that the explanation will amount of the mere correlation of a fact in a phenomenal series by means of a mathematical formula; prediction referred solely to facts, a.o.

2. The deterministic theory

The second modality of mathematizing science is characteristic of the Galileo-Newtonian type of physics. There, we have, in the first place, a mathematization of the theoretical content of science, which is represented by its laws and hypotheses. By this we understand the mathematical formulation of the fundamental hypotheses of the theory and the deduction of their consequences by means of mathematical procedures of standard deduction. Hypotheses (or laws) are regarded both theoretically and methodologically as the basic unit of science, as the elementary unit of signification, testing and evaluation. The theory of the physical method, as introduced by Newton in *Opticks*, has the fundamental goal of determining the idea of *physical hypothesis*. In this case, by hypothesis we mean a mathematical formula doubled by a physical interpretation, a physical idea expressed mathematically and experimentally verifiable. It loses its formal and conventional character, becoming an assertion about reality which must be proved to be true or false.

One epistemological particularity of the new physics, which stems from the specificity of its mathematization, is the local conceptualization of the problem of motion: in the classical mechanics of particles we come across -when dealing with phenomena- a shift from the global (integral) point of view over to the local (differential) one; its motion equations are differential equations and from them one can deduce the trajectories of mass points, given the initial conditions, the restrictions and the laws of force. The status of the new approach to the problem of motion can be understood provided we focus our attention on the significance of the new type of law formulated now. "The differential equation -Einstein pointed out- is that unique form which fully meets the modern physicist's need for causal explanation." This law expresses, in a direct manner, the ideal of the causality principle in the description of nature. The partial differential equation (the abstract-mathematical expression of causal correlation) has turned, therefore, -in Einstein's own words- from "servant" into "master", becoming the natural expression of the elementary ", of "physical reality."

By combining the causal approach with the recourse to experiment (as a modality of founding and controlling hypotheses), the local theories have brought about a new style of theorization, a new type of theory, namely the '*deterministic*' theory, which proposes a new sense of the law and the hypothesis (its constitutive elements), of scientific explanation and prediction, a specific relation between theory and reality, between theory and experience. It is on this basis that the deterministic theories have generated a *realistic* epistemological interpretation. A test case of this statement can be found outside physics as well. We have in mind Riemann's realistic, antiaprioristic outlook on the foundation of geometry, which is grounded in the shift achieved by Riemann from the global approach to the differential approach in the study of space. Too little emphasis has been put, however, on the connection established in this modality of mathematical construction of science between its centering on the scientific *hypothesis* and *law* and the general determination of the status of the *deterministic theory*, the specific understanding of its structure, of its relationship with reality and experience, of the exigencies for consistence and completeness as well as of its manner of evolution.

The deterministic physical theory is seen as a logically organized *body of statements* (hypotheses, laws, principles, theorems). In the explicit logical reconstructions, a physical theory is represented as a set of statements closed under the deduction relations. The signification and validation unit is the scientific law or hypothesis. Being only a 'corpus' of hypotheses, the theory has no *semantic* or *methodological* properties distinct from those characterizing the hypotheses. It is understood and judged in its relation to reality according to the same criteria, standards and exigencies which are specific to scientific laws and hypotheses. Significant in this respect are the reality and completeness criteria formulated by Einstein as far as the deterministic theories are concerned:

> (i) as far as I can judge, from each complete theory it is necessary to ask the following: any element of the physical reality must have a correspondent in the physical theory; (ii) if, without in any way disturbing a system we can predict with certitude, (i.e., with a probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity. (A. Einstein, B. Podolsky, N. Rosen, 1935).

The "elementaristic" modality of understanding physical reality is expressed here by the unity between the conceiving of the "physical reality" and the deterministic explanation. As it is known, the new criteria of physical reality formulated in the contemporary methodology of physics (invariance insertion in the general regularity, inclusion in the system of objective descriptions of nature) exceed this very exigency of the "atomistic" comparison of theory with reality, pointing out the role of the structural elements and exigencies specific to another type of theory.

The "elementaristic" way of understanding physical reality leaves its deep imprint also on the *status of physical theory*. The latter's domain of reference is identified with a general universe of discourse, completely and previously determined, to which theory must adjust itself progressively in its later evolution. The idea of such a universal, "cosmic" application of theory is derived in this way (in the rational reconstruction of theories) not just from the imitation in the philosophy of science, of the metamathematical procedure, as W. Stegmüller believes (W. Stegmüller, 1973), but also from this traditional realistic-naive outlook on physical knowledge. The principal *functions* of theory are now understood also on the basis of the idea of law: thus, *explanation* means the deductive subsummation of the statement describing the fact or the law to be explained to a group of statements, containing nomological statements (expressing general laws) and statements which formulate the initial and border conditions; *prediction*, having basically the same structure as explanation, refers now not only to facts, but also to new objects within the framework of a given system, of an intentioned application of theory; classical mechanics has not only produced more and more precise predictions, but it has also allowed for new types of predictions.

This manner of understanding the status of the deterministic theory has also induced a certain significance of the "axiomatization" of a theory: this represents a *logical* procedure of systematic organization of a set of statements and concepts (their derivation and definition on a minimal basis: the axiomatic system containing fundamental statements and primitive terms). Axiomatization constitutes only a modality of reconstruction, of deeper logical systematization of a body of hypotheses (laws), without heuristic or constructive features.

The status of deterministic theories has been epistemologically expressed, at a general level, by the "standard" (empiricist-analytical) model of theories (Carnap, Hempel, Reichenbach): an outlook on theories in which their structural dynamic and methodological aspects are treated according to the specificity of the methodology of physical hypotheses; the theory is identified with a set of propositions; its testing is carried out by means of experimental and analytical checks which are characteristic of hypotheses; the evolution of theoretical knowledge is reduced to a cumulative, linear process.

3. The abstract-structural theory

The third modality of science mathematization is specific to the general theories ("nuclei of theories"), with a high degree of abstraction of "mathematical physics". It can be illustrated by the abstract formulations of the theory of relativity, quantum mechanics, thermodynamics, classical mechanics a.o. What is characteristic of this modality is the fact that subject to mathematization here is a *complex theoretical structure*; we have, in this case, a "structural mathematization" of the whole theoretical component: a theoretical structure is mathematically defined as a well-determined *unit*. A fundamental role in this process devolves on *axiomatization*. Nevertheless, it does no longer represent a *purely logical* procedure, but a *sui generis* form of mathematization of some complex structure, of mathematical definition and construction of a rich conceptual structure. Theories of this type (comparable, according to Heisenberg, with the "generative structures" of structuralist mathematics) have come into existence through a process of axiomatic abstraction.

The peculiarity of this modality of mathematization of knowledge, as well as its epistemological and methodological implications, has been recognized pretty recently, following the formulation of the "structuralist model" of theories (J.D. Sneed, 1971, W. Stegmüller, 1973), an epistemological continuation of the programme of set-theoretic axiomatization of science as initially proposed by P. Suppes. In this sense, by *axiomatization of a theory we understand the definition of a predicate in the terms of set theory*, a "set-theoretic predicate". For example, the axiomatization of the *classical particle mechanics* is achieved through the introduction of the set-theoretical predicate "*it is a classical particle mechanics* (CPM)" as is shown by the definition below:

Definition: X is a classical particle mechanics (CPM) if P, I, s, m, f, exist, so that:

(1) $X = <P, T, s, m, f>$;
(2) P is a finite non-empty set;
(3) T is an interval of set R of real numbers;
(4) s is a twice differentiable function after t in an open subinterval in T, with $D_I(s) = P X T$ and $D_{II}(s) \subseteq R^3$;
(5) m is a function with $D_I(m) = P$ and $D_{II}(m) \subseteq R$, where $m(u) > 0$ for any $u \in P$;
(6) f is a function with $D_I(f) = P X T X N$ and $D_{II}(f) \subseteq R^3$, for any $u \in P$, and any $t \in T$.

$$\sum_{i \in N} f(u, t, i) \text{ is absolutely convergent;}$$

(7) for any $p \in P$ and $t \in T$, $m(p). D^2 s(p, t) = \sum_{i \in N} f(p, t, i)$.

What is the (metatheoretical) significance of the different elements of this definition? The expression "classical particle mechanics" appears here not as a name of a theory or discipline, but as a *predicate* which must find an application to physical systems. In the set-theoretic axiomatization, one explicitly defines a concept of a higher order than the one of the primitive concepts of a logical axiomatics, a conceptual structure representing the constitutive element of a physical theory. Within its framework, axioms proper are replaced by the *conditions* defining the set-theoretical predicate. Here, "all the axioms describe a *mathematical structure* which is expressed in the totality of relations formulated in axioms." (Stegmüller, 1973, 40). By *model* of a theory we understand an *entity satisfying the set-theoretic predicate*. The definitional conditions (or "axioms") of a set-theoretic predicate can be divided into: (i) *general conditions*, which describe the logico-mathematical categories which the primitive terms belong to; they determine the set-theoretic structure of the entities satisfying the predicate, of the models of a theory; (ii) the "*axioms*" *proper* of the theory, which formulate the specific properties and express the "real content" of the theory. These have been called "structural axioms" and "material axioms", respectively. The first class determines a *possible* model of the theory (a "possible realization" of the set-theoretic predicate). A potential model represents, for the factual theories, a possible mathematical description, within the framework of this theory, of a state of things (in our case "particle mechanics"). A model can be fully determined only by adding also the material axioms. If we are given a distinction between the *theoretical functions* and the *non-theoretical functions* of a theory, we can also introduce the concept of *partial potential model* of a theory, namely the possible mathematical description of physical systems which is constructed *without the use* of the theoretical functions. This model determines the entities to which is applied a given theory by virtue of their description in the non-theoretical vocabulary of the theory.

Setting out from this set-theoretic axiomatization of theories, Sneed introduces the new concept of *the theory of mathematical physics*. The basic idea here is that of logically reconstructing the theories of mathematical physics not as a set of statements ordered according to the relation of logical consequence, but as pairs constituted from a *structural core N*, representing the mathematical structure of the theory (defined by models characterized in set-theoretic terms) and a set *I* of *intended applications.* Thus, Sneed abandons the fiction of a single universal application of physical theory, advancing the idea of a set of *intended applications* mutually interconnected with the structural core by the constraints imposed on the theoretical functions. Then, he introduces the distinction between *fundamental laws* and *special laws* (valid only in some applications of the theory) with the help of the restrictions imposed upon the fundamental predicate *S* (also called "fundamental law") which characterizes the mathematical: structure of the theory. Finally, Sneed introduces the *special constraints* only for the theoretical functions which emerge in the special laws and also a *function of reduction r* (which enables each possible model to have a correspondent in a partial possible model through the "elimination" of the theoretical functions).

The first five constituents: *M, Mp, Mpp, r, C*, where *M* = the set of models, *Mp* = the set of possible models, *Mpp* = the set of partial possible models, *r* = the function of reduction and *C* = the general constraints, represent the relatively *stable* elements of the theory; this quintuple is called by Sneed *structural core of a theory.* The set of special laws *L* and the set of special constraints C_L represent the relatively *unstable* elements of the theory. Together with the relation of *application* of theory, added to the structural core, they make up the *expanded structural core of a theory.* Sneed defines the concept of "*theory of mathematical physics*" by means of the pair $<N, I>$, where *N* is the structural core of a theory and $I \subseteq Mpp$ is the set of intended applications of the theory. *N* represents the formal core of the theory, namely the apparatus utilized to make factual assertions about the fields of the intended applications of the theory.

Sneed draws a line of demarcation between the *factual* ("empirical") assertion that can be made with the help of a theory and the *theory itself.* As a result, he separates the *theory* from the *factual hypotheses* constructed on its basis through the extension of the structural core reaching the stage where only factual hypotheses represent experimentally falsifiable assertions. The *factual content* of the theory is no longer rendered by the total sum of the testable consequences of the theory, but in a "holistic" manner, by the *factual proposition* $I \in A(N)$, which asserts that the intended applications of the theory are "facts" admitted by the theory. It is linguistically rendered by the *factual assertion of the theory*, a single, *indivisible* statement, and not a class of independent statements. This indivisibility is due to the constraints which do not allow the factual content of the theory to disperse in a series of specific hypotheses.

It can be noted that this modality of theory mathematization finds a correspondent in a new epistemological and methodological theory status. The theory formulates *abstract structural models.* The unity of significance and methodology now is *the theory as a whole* because it can no longer be represented as a hypothetico-deductive system meaning a set of hypotheses logically organized by the deduction relation, hypotheses that can be tested by means of their particular consequences. It now represents a unitary conceptual structure along with a set of intended applications. Using a Chomskyan expression, we could say that the theory formulates explicitly the "competence" not the "performance", being, irreducible to a "corpus" of hypotheses, to the logical sum of some individual laws: The theory is not a system of hypotheses. It has a different "ontology", a different relation with reality (new criteria of reality) and a new methodology. That is why the *statement view* of theories characteristic of the standard empiricist model can no longer be valid. This fact is being argued also by the new semantics of empirical theories (constructed by E.W. Beth, B.C. van Fraassen, F. Suppe, a.o.) in which the physical theory is no longer regarded as a partially interpreted mathematical formalism. By contrast, mathematics is relevant to the structure of the significance of the physical language.

This change of view on the status of theories of mathematical physics has been remarkably manifested at the methodological level. As W. Stegmüller has pointed out, the structuralistic view on theories makes possible the understanding and justification of theories "immunity" to recalcitrant experience (referred to by Th.S. Kuhn in the analysis of "normal science"). On the other hand, the new approach allows an original reconstruction of the internal components of theories (laws, meta-nomological statements, a.o.), of the functions of theories (one notes thus the increasingly greater accentuation of their "theoretical" character at the stage of the structuralist mathematization of science in the "structuralist explanations" one "explains", in the first place, the laws that must be used in the explanation of deterministic or statistical type by their integration into the structure: emphasis is put on the necessity of taking into consideration the explicative function of the whole theory) and also of the fundamental metatheoretical exigencies (consistence, completeness, independence), their redefinition for theories understood as "generating structures", and not as mere sets of hypotheses.

Particular stress should also be laid on the understanding of the new way of evolution of theoretical knowledge, of the new dynamics of theories. The difference between the evolution of science centered on *laws* and hypotheses (which corresponds to the empiricist interpretation in the philosophy of science) and that which is characteristic of science, whose unity of cognitive content is constituted by theory as a whole, has been repeatedly underlined by Th.S. Kuhn. Kuhn's criticism is aimed at the very identification of theories with *sets of laws*, that is, at "the assimilation of theories with laws", which does not correspond with the new historic-critical and logical outlooks on theories.

> Theories, as the historian knows them, cannot be decomposed into their constituent elements with a view to comparing them directly either to nature or to each other. That is not to say that they cannot be analytically decomposed at all, but rather that the lawlike parts produced by analysis cannot, unlike empirical laws function individually in such comparisons. (Kuhn, 1977, 19-20).

The difference between *theories* and *laws* is expressed by the differences in the way they evolve and are evaluated. It is on this very basis that the complex nonlinear and noncumulative character of the development of knowledge justifies itself.

At this point, we can give a brief answer to a criticism directed against the structuralist approach to theories, i.e., the one considering the structuralist view as representing a version of instrumentalism (L. Schäfer, 1977). Such an objection does not take into consideration the changing *type* of theory or the specific status of structural theories, of structure-models; it merely asks them to obey the exigencies of other types of theories, that is, of the deterministic ones (which can be reduced to sets of laws); structural theories *can produce laws, hypotheses*, but they cannot be reduced to a sum of hypotheses, they have not a status of hypotheses.

4. The organizational theories

Finally, we could anticipate a new, much more complex, type of scientific theory which should be in line with the organizational orientation in present-day science and which should imply the utilization of some new mathematical formalisms (the theory of categories, the theory of schemes, the theory of catastrophes, a.o.) and of models from other fields of knowledge (linguistics, biology, ecology). So the "generalized" thermodynamics developed by Prigogine, P. Glansdorf a.o., the hypotheses of the evolutive self-organization of matter (advanced by M. Eigen), a.o. can be cited as examples of this type of scientific theories centering on the study of complex organizations, of systems open to environment, genesis and evolution; presupposing, at the same time, statistical and dynamic, structural and functional, informational and energetic elements.

The typological approach to theories outlined in this paper makes it possible to establish distinct kinds of theory structure and evolution corresponding with specific methodological standards and types of rationality. Nevertheless, it does not introduce a final break between the different "*patterns* of science" (as purported by the thesis on "the methodological ladeness of theories") but, as has resulted from the analysis of theory functions, a continuity (a principle of metatheoretical correspondence) is very much in evidence. It presupposes -in the transition from one type of theory to another- the conservation of some criteria and exigencies of the old type, but in a form and with a function correspondingly modified, subordinated to and integrated with more complex standards. The empirical and theoretical progress of science is thus enhanced by a process of growth at the epistemological level.

BIBLIOGRAPHY

Blanché, R.: 1969, *La Méthode expérimentale et la philosophie de la physique*, Paris, A. Colin.

Bohm, D.: 1974, 'Science as Perception -Communication', in Suppe, F. (ed.): *The Structure of Scientific Theories*, Urbana, University of Illinois Press.

Bub, J.: 1974, 'Reply to Professor Causey', in Suppe, F. (ed.): *The Structure of Scientific Theories*, Urbana, University of Illinois Press.

Einstein, A.: 1934, *Mein Weltbild*, Amsterdam, Querido Verlag.

Einstein, A., Podolsky, B. Rosen, N.: 1935, 'Can Quantum-mechanical Description of Physical Reality Be Considered Complete?', *Phys. Rev.* 47.

Kuhn, Th.S.: 1977, *The Essential Tension*, Chicago, The University of Chicago Press.

Schäfer, L.: 1977, 'Theorien-dynamische Nachlieferungen', *Zeitschrift für Philosophische Forschung* 31, Heft 1.

Sergescu, P.: 1928, *Mathematical Thinking* (in Romanian), Cluj.

Sneed, J.D.: 1971, *The Logical Structure of Mathematical Physics*, Dordrecht, Reidel Publishing Co.

Stegmüller, W.: 1973, *Theorienstruktur und Theoriendynamik*, Berlin, New York, Springer, Heilderberg.

v. Weizsäcker, C.-F.: 1976, *Aufbau der Physik*, München, Hauser Verlag.

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