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PROBLEMS OF THE TRANSFER OF THE CONCEPT OF EVOLUTION TO DIFFERENT DOMAINS

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DISCUSSION PAPER

on

Gerhard Vollmer's

THE CONCEPT OF EVOLUTION AS A SYNTHETIC TOOL IN SCIENCE:
ITS STRENGTH AND LIMITS

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Problems of the transfer of the concept of evolution to different domains

Commentary to GERHARD VOLLMER's: The concept of evolution as a synthetic tool in science, its strength and limits.

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Prof. Vollmer has convincingly demonstrated the central position of the notion of "evolution" in current natural sciences, but he also stressed the dangerous exaggerations of this concept. A seductive force lies in the extrapolation of an evolutionary world view beyond the limits where the concrete mechanism of the original evolutional theory has been tested. This can easily be seen by an overview on the current literature where any kind of developmental trend is coined "evolution". A type of superficial world view is thereby arranged where only the concept of "evolution" delivers a verbal bracket around many different kinds of time dependencies of real systems. The proliferation of the uses of "evolution" does much harm to a thoroughly worked out naturalistic world view which after the decay of the mechanistic approach of Newton-Laplace-Boltzmann is highly needed to counteract the desorientation of the layman caused by the sciences.

In the 19. century a strong expectation prevailed that Newton's physics contains in principle all theoretical elements to understand microscopic and macroscopic systems and even the complex phenomenon of human action and intentionality. Maxwell tried to extend mechanical ideas to the electromagnetical field and Boltzmann to thermodynamics. The natural sciences seemed to be on the verge of approaching a true synthesis of a mechanical world view. But history of science decided otherwise. The close upon unity crumbled to pieces; the year 19oo, when the quantum of action was discovered brought about the turning point and with it the seed to the current disappointment.

Science today is an enterprise that is by a large group of people feared and even resented. Strong aversion not only against the big sciences and its energy and time consuming devices is at stake, but we notice a revolt against the rationality of the scientific approach itself, a flight of fancy into mysticism and all other kinds of irrational activities. This negative impression of the whole scientific enterprise on the side of the public has its roots in the incoherent way the laymen is confronted with the stray results in newspapers and unsystematized accounts. He is overwhelmed by the unbelievable, unintelligible, and uncomprehensible facts. Desorientation shows up if interconnexity is lacking, if no systematic attempt is made to find a leading idea (leitmotive) behind the multifarious single inquisitions.

But coherence and interconnexion cannot be reached by verbal means by just coining a superior concept which comprises a few similarities of the disparate sciences. This engenders only an alledged verbalistic unity. The unifying force of the new ordering principle can only be made working if it is coupled to the deep structure of the scientific theories itself. It can be only a heuristic value for the new synthesis to ascertain that there is some kind of evolution in the different domains. The pertinent question is how are the systems itself connected, that means the semantical aspects of the different evolution theories are to be taken into account.

What we do need urgently in this situation is a classification and characterization of the many different traits of the various types of development in order to compare the structural similarities among the many kinds of temporal variation in factual systems. A logical analysis is needed of the following different semantical fields:

i) time dependence of physical systems (is there a common time in the different domains?)

ii) heterogeneity out of homogeneity (is this tendency universal?)

iii) morphogenesis of complex systems (what does it mean in different realms?)

iv) coupling links between adjacent elements of the evolutionary chain (emergence of novel evolutionary dynamics)

Prof. Vollmer has already made an important distinction which points towards a classification of the semantic spectrum of "evolution" involved, the most basic distinction being the descriptive or kinematical versus the explanatory or dynamical aspect of evolution. Let me fill in a few details, which pertain to the semantics of this distinction.

i) The time dependence of all physical systems is by no means obvious.It was without doubt rational by the greeks to assume without any precursor of a law of energy conservation and without any sign of a change within the starry heavens to assume that there is no stellar evolution and what is more the universe at a whole is from everlasting to everlasting. Even today there are a few elementary particles that seem to be stable (like electron, positron, photon) but on a few others (proton, neutrino) a question mark has been put wether their half life is really infinite.

Before 1974 black holes seemed to be absolute stable geometrical objects; then Stephen Hawking discovered the instability of these collapsed stars when they are treated in the quantum-mechanical context.

On the larger perspective the universe was one of the last systems to get a history, although between 195o and 1965 a countermovement established (Steady State Theory) which treated the large scale character of the universe as unchanging (steady state). Up to now there is a minor group of disbelievers in an early hot state of the universe including the famous Fred Hoyle.

There are rather intricate questions concerning the structure of time in cosmology which came to the fore not before the advent of relativity theory. In the 19. century Rudolf Clausius extended the second principle of thermodynamics to very late times. Two questions have kept busy the scientists up to the present: Can the universe as a whole be regarded thermodynamically as a closed system most of all if it is spatially of infinit extent und what is the nature of time going to be when matter in the universe gets scattered to vanishing density:

$\rho(t) \xrightarrow[t \to \infty]{} o$. It is not quite clear what time will be in this

limiting case and doub

the time structure shows up.
The semantical moral is easily to be drawn. Time dependence of physical systems cannot be transfered to systems of arbitrary size without much further conceptual analysis. The problems of transferability shows up more heavily if we notice that not in every cosmological relativistic model a universal time concept is defined. It is one of the intrinsic properties of the highly symmetric Friedman worlds that a unique time parameter can be introduced. Only in homogeneous universes we can define a natural time coordinate, such that all parts of the universe are similar on hypersurfaces corresponding to a fixed value of t. A tiny admixture of cosmic rotation destroys this possibility and in this case it is no longer feasible to regard global developments as ordered uniquely in the sense of one and only one cosmic evolution. The same would be true if by the occurrence of timelike singularities the large scale spacetime contained no global Cauchy-hypersurface; there could of course be single detached galactic evolutions, but it would make no sense to integrate all these local time dependent processes into one global pattern. Therefore it is highly risky to take over evolutionary ideas which are properly defined on a local scale to larger regions. The idea of concatenating "evolutionary" segments in a long chain of cosmic processes (Vollmer, p. 5), leading from the initial singularity to the cultural and scientific evolution, presupposes a well defined concept of time for the whole chain

ii) One of the similarities between biotic evolution and prebiotic formation processes is the transition from an earlier homogeneous to a later (time order!) heterogeneous state. According to present knowledge the very early universe was extremly hot and very symmetric. When matter cooled down on account of the expansion to more moderate temperatures these symmetric states got broken down to states of lesser symmetry. The so called Grand Unified Theories describe this process as a phase transition. One of the characteristics of this changeover is, that new conservation laws got established when spontaneous symmetry breaking occurs, e.g. the so called conservation of the total baryon number is valid only in the cold cosmic epoche where the original symmetry has been lost. Tiny residual effects of this early symmetry are to be expected in form of the proton and neutron decay. The cooling by the expansion of the universe is one of the decisive prerequisites in order that the growth of structural diversity could start at all. Today the universe has evolved in a hierarchy of systems of very many types from micrometeorites to planetoids, planets, stars of all kinds (neutron stars, white dwarfs, red giants) to galactic objects like clusters and superclusters. This multifariousness of forms is however of a transitory state. If current physical eschatology is correct, in about 10^{20} years most of these layers of reality will have decayed and a more or less homogeneous expanding gas will be the endproduct of the cosmic development.

iii) This scenario seems to have little in common with evolution in the more narrow sense to which we are accustomed from the biological domain, the more as Darwin's evolutionary theory is scarcely used to make projections of the far future. Only a family resemblance can be recognized, a tendency to build up more complex systems, when cosmic conditions allow gravitational instabilities to grow. One of the decisive points in the morphogenetic process is the interaction of different levels. The external boundary conditions of galaxy formations are given by the expansion itself. If matter is driven too strongly apart ($\rho \ll \rho_c$ $\rho_c = \frac{3c^2H^2}{8\pi G}$) the original seeds (adiabatic respective isothermal fluctuations) cannot grow and a universe expanding thus violently will not engender any structures at later epoches at all. It will never leave its gaseous state.
If instead the expansion is more calm ($\rho \simeq \rho_c$)[1] and galaxy formation can indeed start, then there are also constraints from

1 If $\rho \gg \rho_c$ then a very early recollaps will prevent any formation of more developed structural entities. The entire lifetime of the universe will be too short in order that fluctuations could grow.

within to galactic "evolution". The key problems involved are the efficiency of the gas → star conversion process and the so called initial mass function (IMF) that expresses how many high mass stars and how many low mass stars arise from the primordial gas. The IMF therefore strongly influences the synthesis of new chemical elements. The process of nucleosynthesis in stars which is responsible for the so-called chemical variation of the original material, the efficacy of the stellar winds and the dissipation of new build elements in the supernova explosions are the crucial determinants that fix the morphological type, the colour and the luminosity of galaxies.
What is at stake in this scenario is a concatenation of different layers of developmental activities. Formation and change of galaxies are externally restricted by cosmic dynamics and internally steered by the variation of the ageing stars. There is a remarkable difference in these two constraints. Galaxy formation can be described as a bifurcation of development. Within a certain interval an instability struggles metaphorically said (but of course not in a Darwinian sense) for an autonomous life against the dispersing influence of the expansion, if successfully then the two branches of development separate and follow their proper dynamics. In an open universe they never meet, in a closed universe where one cycle is much shorter than the time scale of the galactic processes they merge when near the final singularity temperatures rise, tearing all substructures apart.

The major unsolved problem of galaxy formation is the origin of the initial spectrum of fluctuations. All experts agree that although the universe now looks very homogeneous on a large scale (variation of microwave background radiation $(\frac{\Delta T}{T})_{cmb} \leq 10^{-5}$) some initial irregularities must have been present in the early universe to give rise to bound systems which triggered the formation of galaxies in a direct or indirect way.

The experts disagree at which time these primordial fluctuations should be postulated. It would be a kind of weak explanation if they had to be regarded as initial conditions, because then they had to be fed in by hand without the possibility of a deeper understanding.
Furthermore there is some uncertainty on the type of fluctuations to be used, isothermal (or entropy) perturbations in which the radiation pressure is unaltered but matter density varies from place to place, or adiabatic density perturbations in which the photon/baryon ration is unperturbed but matter and radiation density are variable; both kinds of perturbations lead to different scenarios of galaxy formation, entropy fluctuations to hierarchical clustering and isotropic fluctuations to fragmentation. From the entropy fluctuations objects in the mass range 10^6-$10^8 M_\odot$ may condense out soon after the recombination of the ionized matter $(z = 1000)$, galaxies and clusters forming later by the hierarchical method. In the case of adiabatic perturbations systems in the scale of galaxy clusters would condense out smaller units building up by fragmentation. In any way explanations of this kind have the aim to make it comprehensible why there are preferred scales of objects in the universe, why the most extended luminous entities in the universe are gravitationally bound systems of 10^{11} stars with linear dimensions of 10^4 pc. Characteristic masses and extensions are to be understood deductively as results from causal formation processes in the same way as the mass spectrum of stars can be based upon nuclear physics and not by postulating a preferred order of fluctuations in the interstellar medium. The final destination of a theory of galaxy formation and evolution would be to understand the phenomenological non random pattern of the galaxies together with the giant matter free holes. This cellular structure should be explained by gravity alone in the best way without invoking unknown forces and without postulating artificial initial conditions.
The question for the theme of synthesis is now, can we find corresponding forms of building physical systems in other domains of reality. It can be conjectured that the growth of instabilities has thermodynamical aspects - only inequilibrium allows morphogenesis - that is common to every kind of such processes.

In the search for an overarching principle which delivers a frame to all real systems and synthesizes therefore the factual sciences the pure historical aspect has only a weak unifying force. It is by no means selfevident, but now a plain truth of all factual sciences that all known systems show up a time dependent behaviour. A strong unification of the disparate enterprises and a true integration under the roof of evolutionary thinking can only be reached if all selforganized processes from galaxy formations to planetary building and the origin of life exhibit some structural similarities which go beyond the kinematical aspect in the terminology of Prof. Vollmer.

iv) Only if we strife for common elements in the *dynamics* of the different links in the chain, we will get more than a time ordered catologue of adjacent time dependend processes. Explanatory unity demands to look for overlapping or common elements in the pertinent forces that drive evolutionary change in the different domains. If that could be done a dynamic coupling, a steady unfolding without intermediate gaps would be the result. The main heuristic idea to look for these common traits is continuity. The dynamics of the different evolutionary steps of the hierarchy of systems should be comparable in some respect because the forces of the higher level grow out of the lower level in a lawful way. There must indeed be room for emergence. New systems contain an autonomous nomological behaviour and new qualitive features of the compound systems are therefore ruled by forces non valid for the constituents.

This agrees with Prof. Vollmer's conclusion that there is a lower limit for the application of the specific traits of organic evolution. As earlier demonstrated, the dynamics of the formation und development of galaxies - and the same is true for stars und planetary systems - are quite different although I have no quarrels to transfer the three last more peripheral characteristics (Naturalism, Complexity, Progressiveness) to the physical domain. It might be helpful to gain more insight in similarities of all the different domains if instead of a direct comparison of the defining point of view is taken. This has be done partly by the systems theory of the Stuttgart School the so called synergetics inaugurated by Hermann Haken. Coming research on systems theory will show if this theory or one of its further developments will engender the synthesis waited for.

Lit.: H.A. Brück, G.V. Coyne and M.S. Longair, Astrophysical Cosmology, Pont. Acad. Scient. Scrip. Varia Vol. 48, Citta del Vaticano 1982