PHYSICS AND THE TRUE CONTINUUM

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I. Atomism and Matter

There is a long standing, continuous preoccupation with the continuum. By *continuum* I mean here *gapless, true continuum*, as epitomized by the *real axis* of algebra.The paradoxical nature of this continuum is revealed in Cantor's set theory, where the countable set of natural numbers (*aleph zero*) is the first so called *cardinal number,* while the real axis (*aleph one*) is the non-countable set of real numbers, isomorphical with the interval [0 ; 1].
Cantor's set theory seems to be incompatible with the *structure* of matter, as forcefully pointed out by Schroedinger in his charming little book *Science and Humanism* (Cambridge, 1951). There Schroedinger quotes Anaximenes, in order to show that the *atomism* of the ancient Greeks was based on careful considerations of everyday observations, rather than a happy guess: „If you try to assimilate Anaximenes' idea, you naturally come to think that the change of properties of matter, say on rarefaction, must be caused by ist parts receding at greater distants from each other. But it is extremely difficult to accomplish this in your imagination, if you think of matter as forming a gapless continuum. What should recede from what? The mathematicians of the same epoch considered a geometrical line as consisting of points. That is perhaps all right if you leave it alone. But if it is a *material* line and you begin to stretch it – would not ist points recede from each other and leave gaps between them? For the stretching cannot *produce* new points and the same set of points cannot go to cover a greater interval. From these difficulties, *which reside in the mysterious character of the continuum*, the easiest escape is the one taken by the atomists, namely to regard matter as consisting from the outset of isolated ‚points' or rather small particles, which recede from each other on rarefaction and approach to closer distances on condensation, while remaining themselves unchanged."
Atomism is fundamental to physics, since without it *structure, statistical mechanics, variable density* and even *motion* were impossible. The rejection of atomism by Mach and Ostwald in the second half of the 19th century has driven Ludwig Boltzmann to suicide. Latter, the young Einstein -after completing his work on Brownian motion and the reality of molecules- travelled to his spiritual mentor Ernst Mach in Prague and tried hard to convince him on the discreteness of matter. Characteristically, Einstein published in the same 1905 volume of *Annalen der Physik* the „special" theory of relativity, which relies upon Maxwell's *continuous field* theory, as well as his articles on the *discrete* nature of matter (as revealed by the Brownian motion) and the discrete nature of radiation as manifested in the photoelectric effect.

II. Waves as multi-particle phenomena

It has to be clear that the ubiquituous description by means of continuous functions and by equations with *partial derivatives* in physics, is no more than a useful approximations, the so called *hydrodynamic approximation*. Indeed, although all fluids seem to be continuous and all material waves are well described by the wave-equation –an equation with partial derivatives- everybody agrees that waves in plasma, in gaseous, liquid and solid media are macroscopic

manifestations of collective, coherent motions of discrete entities of matter, be they atoms, or molecules. Even electromagnetic waves are macroscopic manifestations of *coherent, self-organized ensembles* of photons (Wesley, 1991)), provided a *critical number* is exceeded (Galeczki and Marquardt, 1996). Once the discrete microstructure of waves realized, the (in)famous „particle-wave dualism" vanishes, since a wave always consists of many discrete particles, but a single particle can never be a wave! This obvious conclusion implies that all claimed „single particle interference", „single atom lasers" and similar fictitious phenomena, are no more than erroneous interpretations of *ensemble, multi-particle effects.* Even the usual equation of Schroedinger describes an ensemble of identical particles, every particle being under the influence of all others. This holds even for gases, as proven by the interference and diffraction effects realized with the help of classical, so called *thermal sources*. No interference phenomena were possible, if the thermal source would not be *partially coherent*. The coherence of a laser beam is no more than the amplification of a pre-existing coherence, as the very acronym *laser* states.

III. The mass equivalence of potential energy

After pleading the cause of the fundamentally discrete nature of both matter and radiation, we turn now our attention to the *mass-energy equivalence* $m = E/c^2$, expressing the fact that any form of energy E possesses an inertial mass m. A blatantly curious fact is the total absence – with very few exceptions, like Leon Brillouin's last book „*Relativity Reexamined*"(1970), from all textbooks and monographies of *potential energy*. All books on „special" relativity show a pathological amnesia by talking about *rest* and *kinetic energy*, but carefully avoiding even the mentioning of *potential energy*. Consciously, or not, this seems (to me) to be related to the necessarily *negative sign* of E_{pot} , implying a *negative mass*. Most interesting, but not less important, is the necessary association of potential energy with a *truely continuous mass-density distribution*, seemingly contradicting the fundamentally discrete structure of matter. The truely continuous mass distribution is, however, compulsory, if we are to take the relation $m = E/c^2$ seriously, which –in view of the energy eliberated in fission processes- we are compelled to do. Indeed, as first pointed out by Heisenberg, the energy liberated by the explosion of an atomic bomb originates in the strong *binding energy* of the nucleus – evidently a specific *potential energy*.
On purely logical basis then, we have to accept that matter consists of a *superposition of discrete* (elementary) *particles* and a *truely continuous, gapless, density distribution* associated with the *ubiquituous potential gravitational energy*. We stress once more that this is a logical implication, quite independent of the penetrability of the *continuous background* to discrete, ordinary matter.

IV. The ideally rigid continuous medium

The unexpected conclusion of the present analysis is the necessity of *physical coexistence* of *material discretum* with *material, true continuum*. *This continuum is of gravitational origin*, since gravitation is the only long-range, universal interaction, as early realized by the genius of Newton. Charged systems, from atoms to galaxies, display a general tendency toward neutrality, therefore a truely continuous, electrical background is non-existent.
The fundamental difference between gravitation and electricity is manifested in the everyday presence of all kinds of electromagnetic waves and in *the total absence of gravitational waves*. Gravitational interaction is apparently *instantaneous*, as reluctantly assumed by Newton and latter suggested by many researchers from Laplace to Eddington and Van Flandern. Indeed, from the astronomical evidence within the solar system, Laplace concluded that the speed of propagation of gravity has to be at least $10^8 c$. This limit has been pushed to

10^{10}c in the last years by Van Flandern, thus strongly suggesting instantaneous propagation of gravity. To quote Van Flandern: "Anyone with a computer and an orbit computation or numerical integration software can verify the consequences of introducing a delay into gravitational interaction. The effect on computed orbits is usually disastrous because conservation of angular momentum is distroyed. Expressed less technically by Sir Arthur (Eddington), this means: ´If the Sun attracts Jupiter towards ist present position S, and Jupiter attracts the Sun towards ist present position J, the two forces are in the same line and balance. But if the Sun attracts Jupiter towards its previous position S´, and Jupiter attracts the Sun towards its previous position J´, when the force of attraction started out to cross the gulf, then the two forces give a couple. This couple will tend to increase the angular momentum of the system. And, acting cumulatively, will soon cause an appreciable change of period, disagreeing with observations if the speed is at all comparable with that of light.´"
Since, according to both Anaximenes and Schroedinger, the true continuum cannot be either compressed, or dilated, the *continuous gravitational background* could well be seen as the long sought after *ideally rigid medium allowing instantaneous action at a distance.*
In the present context one can mention Rosen's „bi-metric" gravitational theory started in 1940, which also assumed a *truely continuous, static gravitational background* , with a (schizophrenically) associated *background metric* distinct from the *Riemannian metric* associated with ordinary matter, but nevertheless, predicting (just like Einstein's „general relativity") *gravitational waves* supposedly propagating with the same velocity c as the electromagnetic waves.

V. The folly of the search after gravitational waves

87 years ago Einstein predicted in his *linearized general relativity theory (GRT)* gravitational waves propagating with the velocity of light in vacuum c . The detection of these elusive waves has been since 1969 for years the goal pursued by Joseph („Jo") Weber, who claimed several times to having detected gravitational waves. His supposedly gravitational effect was, however ten tausend (10^4) times larger than predicted by GRT and have been questioned by several researchers not commited to GRT. After 1975, although Jo pursued further the development of his several tons heavy aluminum cylindrical detectors, nobody continued to take seriously the supposed detection of gravitational waves. Nevertheless, since the three classical test suggested by Einstein (the precession of the Mercury perihelion, the bending of starlight near the Sun and the red-shift caused by the strong gravitational field of the Sun) provided only a shaky experimental basis for GRT, the quixotic hunting of gravitational waves continued. In the middle of eighties the idea to use huge Michelson type interferometers to detect tinny changes in length –caused supposedly by gravitational waves- gained popularity in general relativistic circles. Three such interferometers have been built, all three requiring about 200 millions of US$: in Itally bellow Gran Sasso, in USA the LIGO project and in Germany, south from Hannover, the GEO 600, the number 600 staying for the lenght in meters of the (evacuated) interferometer arms. The expected changes in length are of the order of 10^{-16} meter, about one over thousend of the diameter of an atomic nucleus! Recently (January 30, 2002) the prestigious German daily *Frankfurter Allgemeine Zeitung* reported the successful accomplishment of two weeks of measurements, in which all three Michelson interferometers indicated –supposedly- the same effect. The results of the data analysis are not expected before June 2002 and there is great hope that gravitational waves will finally be confirmed.... The *march of folly* continues unceasingly.

VI. Continuous *vs.* discrete time

Approaching the end of this article, I shall leave the continuous gravitational background and

discuss shortly the nature of the time parameter used in physics. Since the times of Newton and (latter) Hamilton, the identification of the time parameter with the continuum of real numbers has never been seriously questioned. Also, reinforced by Boltzmann´s H-theorem, unlike the spatial parameters x, y, z, the time parameter has been accepted as one-directional, a fact known as *the arrow of time*. In the early days of the movie (*kinema*), the philosopher Henri Bergson –one of the most prominent thinkers about time- made a very important analysis of the *illusion of motion* introduced by the movie. To make a film, so Bergson, one takes a *discrete set* of pictures or *frames* and afterthen unwinds –or roll off- the recorded frames with a high enough speed, therefore creating the illusion of motion. However, one has to clearly distinguish between *real, dynamical motion* and *illusory, movie motion, in which no real causes (forces) are involved.* The most baffling difference is that *unlike real motion, movie like motion is reversible*, generating both paradoxical and comical processes. In modern language one can say that the making of a movie amounts to *discretize* some *continuous, real process*, or to make an *analog to digital conversion.* ***The digitalized, discrete frame sequence is reversible, while real, natural processes are generally irreversible. Just like physical continuum associated with the gravitational background is incompressible, physical time is irreversible.***

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