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EINE KLEINE NACHTPHYSIK

dedicated to George Marx on the occasion of his 60th birthday

by

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Abstract

Some thoughts are given to the antropic principle and its traces in physics.

The non-informative title of this essay stems from the fact that it was written on a night flight when I was stirring up my memories. The reader who finds its scientific substance somewhat thin should blame that on the environment where it was scribbled.

In the post-war period George Marx and I struggled together, each of us in his country, to raise theoretical physics in central Europe to a level fitting for the intellectual potentialities of this area. Whereas I then turned to the hard mathematical facts he has reflected a great deal about the functioning of the universe, a subject rich in philosophical speculations. In this contribution I will also indulge in some related thoughts because it seems to me that some old ideas of men appear now in a new form. Theologians always wanted for men, the coronation of the creation, an appropriately distinguished place in the universe. Though we are admittedly at a rather cosy distance to the sun, our position in the galaxy or galaxy cluster seems to be nothing special, we did not get a first class ticket for our journey. In contradistinction the universe we are living in does indeed seem to be very distinguished. If we change its laws or other conditions just a little bit we do not only erase a subtle phenomenon like life from its surface but the scene changes far more drastically. I shall illustrate this claim by going through the history of the universe but making some slight deviations from its course.

1) At present one believes that the universe was created by a kind of quantum mechanical tunnel effect where the energy for the matter was paid for by the negative gravitational energy, the total energy being zero. The relevant time scale for such a spontaneous process is the Planck time 10^{-43} sec and the remarkable fact is that this fluctuation was so successful that it lasted 10^{18} sec. Starting an expanding universe is like launching a satellite, if you do not give it enough thrust it falls back to the ground, if you give it too much thrust it soon disappears into space. Only for very precisely selected initial conditions it will stay in orbit for a long time and this is what happened with our universe. Indeed, we have seen that on the relevant time scale its age is 10^{62}.

2) We now think that the laws of nature have undergone an evolution and what we see now is the result of some freezing out process. Therefore the masses and coupling constants may be the results of historical accidents, as incalculable as the thickness of the ice on a lake after a cold night.

In any case if they had turned out slightly different the appearance of the universe would change completely. Just consider the following possibilities

a) The mass difference between the proton and the neutron is a sensitive effect, the small difference between various contributions. Changing the coupling constant a little bit it could easily come out the other way and make the proton heavier than the neutron. In this case the proton would be unstable and there would be no hydrogen, the basic raw material for cooking heavier elements. Thus the dark landscape of the universe would then be marked only by neutron stars.

b) The ratio between the mass of pions and electrons, being the lightest charged particles of families at best remotely related, is not calculable at present. A theory where the pion has a mass of 5 MeV but the electron 140 MeV seems equally good to the elementary particle physicist but would put the solid state physicist out of job. In this case the pion would be stable and matter consisted not of e^- and nuclei but of π^- and nuclei. The π^- would destroy heavier nuclei by the reaction $p + p \rightarrow \pi^- + p + n + 5$ MeV but even the fate of hydrogen would be wild. Since the pions are bosons the binding energy of hydrogen would not increase $\sim N$ = number of hydrogen atoms but first like $Ry \cdot N^{5/3}$ until the kinetic energy of the proton stabilizes the system. This happens at densities $(\hbar^2/M_p e^2)^{-3} = 10^{10}$ times the density of water. At that stage it becomes a jellium of protons in a negative charge background which practically has no kinetic energy, its binding energy per particle is $(M_p/m_e)Ry \sim 2000$ Ry. Thus in this scenario we have a potent and space saving fuel but there would be no rockets which could use it.

c) A universe with only hydrogen and perhaps a little helium would be dull, for life we need some heavier elements. To produce them there is the bottle neck that two α-particles do not stick together for any length of time and unless a third one happens to be around to make C^{12} the further evolution of elements is blocked. How one gets through this eye of the needle depends sensitively on the properties of the excited states of Be^8 and C^{12} and thus is essentially influenced by the strength and range of the nuclear forces. Yet the evolution of life as we know it depends on the existence of heavier elements. This list of the hurdles to the creation of life can easily be continued and experts from many fields can throw in some more facts which would impede the existence of life.

In view of all that some people thought that it should be a guiding principle for the laws of nature to be such that they eventually lead to life. It is called the antropic principle and as physicist one has the duty to see how one could find a reason for that. There are several attitudes possible.

A) One can except it by an act of faith and say that when the good Lord created the world he did it exceedingly cleverly so that it works so well. This seems to be the most reasonable answer in our present state of knowledge but it may not satisfy people who like to play with their imagination.

B) One can adopt a Darwinistic point of view and assume that there have been many universes created but most of them were no good, either they collapsed too soon or the separation of the various interactions was all messed up e.t.c. Once there was finally the lucky strike where everything worked. Then intelligent creatures evolved and wondered why everything conspires to make their existence possible. Some people may like this idea but unless we see some traces of all these abortive universes there is not much scientific substance to such a hypothesis.

C) Since people now find selforganization for many systems without paying much attention to a realistic representation of matter it may be that self-organization is a feature as general as the tendency to equilibrium and some sort of life could also evolve under quite different circumstances. For instance, even in our first scenario where there are only neutron stars, it could be that at its surface some highly organized structures come into being. As the time scale in nuclear matter is speeded up compared to ordinary matter by about a million they would evolve much faster and after a few thousand years higher civilizations may populate this otherwise dull scenario.

Obviously by such considerations one easily drifts into science fiction. To describe the situation in more scientific terms one might say that the present situation in physics is somewhat like in mathematics in the post-Gödel area. Hilbert had thought that one could cast mathematics in a closed rational system where every truth is provable but Gödel had shown that this is not so. Similarly one could have hoped that physics became a closed rational system where every important fact could be deduced from the fundamental laws. It turned out that the facts important for us appear to be

more of an accidental nature and beyond scientific deduction. What is engraved in the fundamental laws does not seem to care too much about us. Maybe our present understanding of nature just reflects the fact that our mind can readily grasp simplicity and symmetry but has a hard time seeing through complexity.