

GOD'S TRACES IN THE LAWS OF NATURE

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Dear Colleagues,

Far from being able to give a comprehensive review of the vast subject of the relation between Science and Religion, I want to comment on a few points which have not been sufficiently put into focus yet. Many of you might remember that some years ago our highly esteemed colleague Germain told us that his father tried to dissuade him to go into science. He feared that he would lose his religious faith as science conflicts with religion. After thinking for half a century about this question, I am reaching the opposite conclusion. Of course we all have to start from the same facts and I don't claim that I have the only rational way of looking at them. However I think that my view is consistent and logically tenable.

When I speak about religion, I shall restrict myself to monotheistic religions and more specifically to God as revealed in the Bible. Here I want to discuss three aspects, the creating God of the Genesis, the guiding God of the old testament and the loving God of the new testament. All three features have their correspondence in natural science. It seems to me that when looked at the right way science does not conflict with the religious world view but makes it more glorious.

1. THE GENESIS

To get trivia out of the way, let me start with the following remark: 'Everything can be described on different levels'. There may be a simpler but coarser description which conveys the point one wants to make, though in some ways it is oversimplified or even wrong. There will be a

more accurate and detailed description which however is too complicated to bring one's point into a focus. This has nothing to do with religion and there are plenty of examples in science. Take for instance chemistry where the atoms of a molecule are represented by little balls and the bonds between them by little sticks. This notation has become a way of thinking and proved to be so fertile that modern science cannot live without it. Yet we know that it is incorrect. Not just because of the trivial reason that on a sheet three-dimensional objects must be represented by two-dimensional projections but because the whole mental picture does not apply. The correct description is furnished by the Schrödinger equation. It operates with completely different notions and deeper questions like the stability of matter or Bose-Einstein condensation of atoms do not appear in the simpler picture. But a more refined analysis shows that instability does not appear on earth but only for cosmic bodies which are gravity dominated and B-E condensation requires for its realization the high technology of ingenious experimentators. Thus, chemists may happily go on using their simple pictures, for their purposes it is good enough. I think with Genesis we are in a similar situation, it obviously does not meet our present scientific standards. But what we have learned from our chemistry example is not to criticize the coarser description once one has a more accurate one. This criticism is trivial and can be left to more modest intellects. The question is, does the more accurate description modify the outlook of the coarser one and this is what I want to do now.

From Genesis, I abstract the following message. The universe was created in a single act and the powers of its creator must have infinitely transcended all human capacities. Expressed in this form, Genesis is not only supported by science but also brilliantly illustrated by it.

The big-bang picture of the origin of the universe as a huge exploding fireball is now so well established that I suppose it to be common knowledge. At least what happened after three minutes of its creation is well supported by observation. The first three minutes remain a realm of scientific speculation since their traces have been extinguished but this should not concern us here. To start I have to sketch the laws which governed this terrific explosion. At first sight it seems unexplicable because where should all this immense amount of energy come from? Nevertheless, according to Einstein's theory of gravity this should not be a problem. The gravitational energy is negative which in a high-density object may get so huge as to compensate the positive energy of matter. In fact, in this theory for a closed universe the compensation is exact and its total energy is zero. Amazingly

energy conservation does not forbid the *creatio ex nihilo*, however it might be inhibited by some barrier. Thus, the state of nothingness, 'the vacuum', will be unstable against big bangs. If you like, you may picture 'the earth was dark and vaste' of Genesis as the vacuum of quantum gravity and 'there be light' as its breakdown due to its instability. If the whole universe appears in a small region, its gravitational energy will be near $-\infty$ so the energy of its matter must be close to $+\infty$. That is to say, the newly created universe will be very hot and all possible particles will be created. The reason why now we can continue the speculation scientifically is that on a small scale we can reconstruct such a situation using high energy accelerators. At this point, as a physicist, I cannot refrain from sticking in some orders of magnitude; in the cosmic background radiation we actually see the last glow of the first light. By the expansion of the universe the wavelength of this light has been stretched proportionally and is now about 1 mm. With the biggest accelerators, we can reach wavelengths of 10^{-17} cm that is to say smaller by 10^{16} . Thus, we can realize states, which occurred when the universe was smaller by this factor 10^{16} which means when it had the size of the sun since it now measures 10^{28} cm across. Hence we can now leisurely study what comes out of the vacuum in such a highly concentrated situation. High energy events where thousands of particles are created out of vacuum appear chaotic. Nevertheless closer analysis reveals a high degree of symmetry referring to an 'inner space' not visible on the macroscopic scale. This symmetry led people to guess the laws which govern the behaviour of these particles. The deduction of these laws was not logically compelling but used above all arguments of beauty and simplicity. Wonder over wonder as experimental analysis and calculations were refined, one found theory and observations approached each other and are now in agreement within the level of their accuracy of about 1%. Thus we seem to possess the laws of creation and the following speculations about its creator come to one's mind.

1.1. *God is spiritual, omnipotent and omnipresent*

The laws reveal their simplicity and beauty not to the simple mind but only to minds at home in higher levels of mathematical abstraction. Thus their architect must possess these highly spiritual qualities and He must have engraved them in nature in a way beyond human understanding. These laws are simple on a conceptual but not on a computational level and we need all the powers of our supercomputers to work out their conse-

quences. Yet these tiny particles, 10^{-15} cm across, follow these laws and somehow can easily solve these difficult equations in 10^{-25} sec. On a human scale this appears far beyond anything feasible which to me represents a sign of God's omnipotence. The omnipresence is directly shown by the fact that, as far as we can see, these laws are valid all over the world.

1.2. *Man is God's image*

If we call these laws 'Gods words' ('the logos') then man is able to read them in an unexplicable way. One cannot argue that these laws are just archetypes set in our brain by evolution since our evolution of life never met energies of 100 GeV or distances of 10^{-16} cm. The mathematical images appearing in our laws were created by man only in the past decades and must have received their inspiration from somewhere else. Somehow the human mind is tuned to God's wavelength.

1.3. *Man is the coronation of the creation*

It is often argued that man is nothing, being only an infinitesimal part of the universe. But I think lifetime or size is not what matters, even the universe was once as tiny as the head of a pin. What is important is that we are able to understand the laws of nature and as far as we can see we are the only ones. It is true that there are about 10^{10} galaxies, each containing about 10^{11} stars and many of them might have planetary systems. Thus, the probability for the existence of incredibly robust unicellular creatures somewhere is overwhelming. However, for these cells to get organized to higher forms of life took on earth 3 billion years. For this evolution we need planets with a stable climate over such a stretch of time and this will be highly improbable. Even granting that still one has to wait until dinosaurs are eradicated and then a 'Newton' needs to be born for science to emerge. How long this chain of events takes somewhere else is everybody's guess. The probability for higher extraterrestrial intelligence is the product of a huge and a tiny factor. Which one wins out cannot be pinned down. Thus the outcome can only be settled by observational evidence and so far there is none.

Up to now, I have been talking about a creator without saying why I assume there is one. In fact, positivists will say this in an unprovable and unnecessary hypothesis and this is logically correct. But the positivistic attitude, though sometimes quite healthy, may also be counter-productive because an unprovable hypothesis may very well pave the way to deeper

understanding. Let's return to our scientific example. When Demokritos postulated the existence of atoms he thought this was a way to reconcile the indestructibility of matter with its ever changing forms. At this time, one was far from being able to prove this assumption and up to the beginning of the 20th century positivists objected to it. Now we not only have to say that it is as if there were atoms but we can even see them. So everybody thinks that Demokritos was right. However, atoms show some unexpected features and it's not so clear that what he was talking about really exists.

In science we always start with an 'as if' situation in order to relate the unknown to the known. To show in which sense a putative element exists is not the most rewarding task. Rather one has to show that its assumption leads to a consistent scheme. If it turns out to be inconsistent, it ought to be modified, if it works well, the 'as if' is eventually dropped. Take an example from pure thought, namely from mathematics, our notions of numbers. To start with we have the natural numbers 1, 2, 3 They exist in the sense that we can count them with our fingers. However, they are not a perfect scheme since subtraction is not always possible, it is as if they are only part of a more complete set. Indeed by incorporating 0, -1, -2, one arrives at the integers. At this stage, one does neither worry that we do not have negative fingers nor ask in which platonic sense the new elements exist, but just notes that one can always subtract. The scheme still lacks perfection since one cannot always divide so one incorporates the fractions $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{3}$, Now one has a nice scheme and these numbers are called the rational numbers. Yet, there must exist more numbers. Already the Greeks found to their horror that the diagonal of a square cannot be expressed by rational numbers. Such numbers were punished by being called 'irrational' but it was found that they are the majority. Though called irrational everybody believes that these numbers exist. Not so much because they can be realized by mental constructs like the Dedekind cut or converging ultrafilters but because they lead to a powerful and consistent tool. Such a process has been repeated on and on in mathematics up to nonstandard analysis, which essentially assumes that limits always exist. But then the problem is that the limit may not have the desired properties. Thus returning to our discussion we have to state which properties the creating God shows. First of all it is clear that God must possess properties so vastly different from what we are used to. We can state:

1) *God the creator cannot be pictured by any natural object.*

On this point the three abrahamic religions agree but our reasoning suggest even more.

2) *God the creator cannot be called the good Lord or the loving Father.*

In fact, gnostic theologians thought the creator was cruel and terrible. But to me it seems that these adjectives do not apply either. Admittedly, the early universe was a terrible place and completely hostile to life. But since there was nobody to complain about it, this can hardly be called cruel. But more generally

3) *God the creator does not show any personal features.*

I think that this is the reason why many scientists believe in some sort of creator but have difficulty in picturing a personal God. Such features appear only if we follow His traces to the further stages of the evolution of the universe.

2. THE GUIDING GOD

Here I have to discuss first the limitations of the predictive power of the laws of physics. By its laws the state of a system at a later time is determined from the initial state by the equations of motion. Great pains have led to equations where the solution is unique and therefore laws are deterministic insofar as the present determines the future. This also holds in quantum mechanics except that there are no states where the values of all observables are completely fixed so not only the future but even the present contains uncertainties. More importantly when considering the whole universe, we can never completely determine its state because only finitely many measurements are feasible. Of course we are free to measure whatever we please and such a finite number of measurements determines a state of the system within what is mathematically called a weak neighbourhood. Now for a system as complex or chaotic as the whole universe the state at much later times depends so sensitively on the initial state, that any weak neighbourhood leaves enough leeway that practically anything can come out of it. This does not only concern minor details but also which path is chosen at important crossroads that eventually determines the future fate of the universe. Actually the state of the universe at a much later time is, in Gellman's words 'the product of many frozen in accidents'. In particular our present form of the laws of nature contains many parameters, masses of particles and strengths of interactions, which we cannot explain and which may be the result of frozen in accidents. However, whether the universe is a livable place or not depends essentially on such quantities as I shall now illustrate with a few examples.

2.1. *The age of the universe*

The big bang is the explosion of a highly compressed system kept together by gravity. How long this keeps expanding depends on the strength of the initial thrust relative to the gravitational pull due to its mass. It is like launching a satellite into an orbit which should circle the earth many times. With too much thrust it escapes the earth, with too little it falls back. It took humanity some time to learn this fine tuning but for the universe it needs far finer tuning. For the big bang the characteristic time to collapse again is the Planck time 10^{-43} seconds. To get a universe capable of producing life like ours you need about 10^{10} years = 10^{17} seconds. Thus, you need fine tuning by a factor 10^{60} .

2.2. *Stability of matter*

There are far more reasons favouring instability of matter than there are for stability. One obvious condition for the existence of matter is the stability of the proton. But there is its neutral brother the neutron, and which of the two is the stable one depends on which one is lighter. Usually, the neutral brothers are lighter but here we have an anomaly, which appears accidental, the neutron is heavier by about 1/1000. Thus it decays in about one quarter of an hour into a proton which then is stable. If it were the other way around, there would be no stable proton and therefore no hydrogen. Not only there would be no water for us to drink but there would be no earth, no stars, only lumps of neutrons held together by gravity floating as dark matter in the vast space. A *triste* world.

2.3. *The formation of heavier elements*

For life to evolve we need not only hydrogen but also carbon and oxygen. The big bang starts out with hydrogen which in the concentrated phase may fuse into He nuclei (= α -particles). The ladder to heavier nuclei is however missing one step. 3α -particles give carbon (C^{12}) and 4α -particles give oxygen (O^{16}) but 2α -particles don't stick together at all. This means that the corresponding nucleus Be^8 has no ground state but only more or less short-lived excited states. A carbon nucleus can only form if within the short lifetime of Be^8 a third α -particle comes along with an appropriate energy and they all fuse into C^{12} . Whether this actually happens essentially depends on the exact form of the nuclear forces and their strength relative

to the electric repulsion of α -particles. In some parameter space is only a small window through which such escape to heavier elements is possible.

These examples of the accidental nature of the circumstances in which life can emerge are only three among the many which have been collected in thick books.

The Anthropic Principle

It states that on the many crossroads met in the evolution of the universe the path chosen is the one which eventually leads to life.

Now some explanations are in order:

1. It is called principle not law of nature since it is not deducible from fundamental laws.

2. It is called anthropic since it refers to the emergence of man. At this point I prefer to talk about the emergence of life as the necessary conditions for the steps from life to men are even less understood.

3. Some people think it is not even a principle but a tautology as there would be nobody to state the principle if the conditions were not met. So maybe the vacuum fluctuations which lead to the big bang also lead to many different big bangs and among these innumerable universes there was bound to be one qualified for producing life and this is ours. Though logically possible this kind of Darwinistic explanation lacks any scientific substance as long as we do not see any signs of these many alternative universes.

4. One might think it may be explained in probabilistic terms according to the idea that all roads eventually lead to Rome. I don't believe this because of the following reason. At the beginning there must have been the state of infinite temperature which assigns all possibilities the same probability. Since their number is legion whatever comes out is exceedingly unlikely. But then one is not interested in a particular possibility but in the occurrence in any one of those where the highly ordered structures which we call life exist. But this subset of all possibilities is such a minority that the probability is still practically null. One might object that there can be situations where life develops by necessity but then these situations are exceptional on a global scale. Thus a priori probability will lead us nowhere.

At this stage, it is tempting for theology to take advantage of the failure of rational explanations of the anthropic principle and to say it is as if God were guiding the evolution of the cosmos such that eventually He

can create His image. This immediately triggers a question. First I have been talking about a God who uses His laws to create the universe and now I talk about a God who uses the ambiguities left by his laws to let the universe develop in the direction he likes. Is this still the same God? I must refute this question because it presupposes an illegitimate picture of God. The notion of sameness, though obvious for material objects, may not apply to immaterial ones. For instance the question whether I wake up in the morning at the same point in space where I fell asleep the night before cannot definitely be answered. First we tend to say yes but remembering that in the meantime the earth has moved a bit around the sun, one would say no. Only by uniting all points in space to 'the space' we can say I wake up in the same space but whether at the same point depends on the frame I choose.

The great breakthroughs in science have been made by uniting into a more universal entity things which first appear different to us. This started with Newton who had the inspiration that what pulls the apple onto his head is the same as keeps the moon in his orbit around the earth. This went on to Einstein who united all points in space with all instances of time into the 'Minkowski space' and recognized that this was the natural arena of all events and finally leading to Glashow, Salam and Weinberg who united forces which appear entirely different, namely the ones governing electromagnetisms with the ones producing β -decay. So the question whether space and time are to be considered the same is not an unqualified 'yes' or 'no' rather a 'no but they are simply different aspects of the same object, namely Minkowski space'.

On its way to further unification, physics is now stuck at a 'trinitarian' situation. We are left with three fundamental forces, gravity, electroweak forces and nuclear forces but most of us physicists think they are just different aspects of 'the Force' which we don't know yet how to formulate. Coming back to God's sameness if one searches for an answer, it would be reasonable to say 'It is God who and by whatever means guided the evolution towards the creation of men, but whoever wants to emphasize different aspects of this long road should not be burned as heretic'.

3. THE UNIVERSALLY LOVING GOD

When we turn from evolution of the universe to evolution of life we encounter as the main driving force Darwin's 'survival of the fittest'. Though

originally banned as heresy, now it seems obvious if not tautological: fit is what enables survival. However, the great watersheds were when evolution turned against this dictum. I shall call it 'antidarwinistic' though my biological friends tell me that Darwin had already understood that. The first crucial crossroad we encountered before. The earth became livable about 4 billion years ago and soon after unicellular organisms developed. They perfected fitness to an amazing degree. They can live in the deep sea where magma bursts into the water and it is several hundred degrees hot. They are found in polar ice or in places of the earth mantle where nothing else can live. Above all they are immortal in the sense that they don't die of old age like us. According to Darwin's dictum this should be the endpoint of evolution and indeed it took about 3 billion years to get beyond it. There must have been innumerable abortive attempts but once multicellular organisms succeeded they spread like a firestorm around the earth and created this marvellous diversity of species we find today. It was like a phase transition in physics but whether this was progress may be a matter of dispute. Owing to their immortality, the unicellulars are still among us, in fact they are the main contributors to the biomass on earth. Yet there can be no doubt that though mortal we are their masters. We can cultivate them, manipulate them, exploit them.

These kinds of watersheds to higher organisational units kept reappearing along the way up to the evolution of men. About 40 thousand years ago the Neanderthals were replaced by Chromagnons despite the fact that the individual Neanderthal must have been a highly fit creature in order to survive under the terrible climatic circumstances of that time. Presumably, they lacked organizational skills so they lived in small clans each including a handful of people. On the other hand Chromagnon reached a higher cultural level so they could coordinate large tribes. As a consequence the Neanderthals had no chance of survival despite their fitness, again a sign of antidarwinism. This ability – coordinating even larger tribes and people – brought about yet another phase transition in human evolution which in turn led to amazing architectural and artistic achievements of the ancient cultures. The idea of a nation as the human unity is also reflected by the religions of the various people. They mainly served to deify the ruling class and their Gods had a certain local flavour. Even when finally monotheism was reached as presented in the old testament, God was seen in relation to some people. In an act of universal validity, as the statement of the ten commandments, God first identifies himself as the God who led the people of Israel out of Egypt. By necessity the next step in human evolution was to

see the whole humanity as the relevant unit. This step was taken by Jesus Christ who turned to people irrespectively of their social level, professional activities or ethnic origin. He did not divide humanity into friends and enemies, on the contrary he preached love extended to your enemies. This is obviously in our sense antidarwinistic but necessary to bring peace to mankind. Thus, I see the importance of Christianity and also the reason for its success in its universality: one God for all people. Unfortunately, the corresponding phase transition in human evolution had not yet taken place, it is as if the nationalistic thinking were genetically engraved in our brains. Our generation still learned at school 'Recht ist was dem Volke nützt, Unrecht was ihm schadet' and even today all over the world fights get ignited by ethnic prejudices. Do we have to wait the genetically relevant time of 40 million years of Teilhard de Chardin to reach his Ω point? I hope not as I am afraid if we don't reach it earlier we will never get there.

To summarize I see in the evolution of the cosmos a continuing strive for higher organisational structures leading up to humanity. Nietzsche declared God to be dead since Darwin could explain the biological evolution 'naturally'. This means you expect of a living God a spectacular miracle and to show us that he breaks his laws. As J. Monod emphasized in his famous book *Le hasard et la nécessité* this does not seem to happen in the biological evolution. It does not contradict the fundamental laws of physics but it cannot be predicted by them either. It could have happened but need not happen the way it did. We have seen such a situation all along the way in the evolution of the universe. At crossroads it always took the path such that finally we could evolve. If in a vessel with gas one atom is near a corner this does not contradict any law nor if there are two. If all are there we would call it a miracle since it contradicts all our probability estimates. What is now the probability that at all bifurcations the universe evolves so as to create more ordered structures? Surely low but how low is hard to estimate convincingly. I don't want to call it a miracle but I see in it the guiding hand of the invisible God.