

Man, Nature and the Universe

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Whenever we probe into the writings or sayings of the wise and the thinkers of the past and compare them with their present scientific counterparts, we encounter a commonality in the following respect. The discussions centre on a triangle whose vertices are:

1. Man.
2. Nature.
3. Universe.

There are interrelations of any of the three vertices with the other two. Moreover, an attempt is made to make all three fit into a self-consistent picture.

Experience has warned us time and again that a self-consistent picture may not necessarily mean the correct or factual picture. Rather, it may well happen that a basically sound description appears full of contradictions because all facts are not yet at hand. Didn't Arjuna complain to Krsna in the *Gita* about his apparently contradictory words?

*vyamisrene'va vakyena,
buddhim mohayasi'va me
tad ekam vada niscitya
yena sreya'ham apnuyam*

[Chapter III, Verse 2]

With an apparently confused utterance thou seemest to bewilder my intelligence. Tell (me) then decisively the one thing by which I can attain the highest good.

In modern times man occasionally perceives in nature an apparently contradictory

behaviour. The advent of quantum theory brought in a culture shock to theoreticians accustomed to the Newtonian expectations of definitiveness in the behaviour of nature. Special relativity gave a jolt to the ingrained perception of time as an absolute, uniformly flowing entity. But the overall self-consistency of the scheme began to make itself manifest gradually. Today we understand the micro-behaviour of nature better than at the beginning of this century, but several foundational issues remain.

How are laws of nature related to the large scale structure of the universe? Does the universe determine the laws or is it *vice-versa*? Are both unique? Or could there be many possible universes in which nature follows the same laws? Or does the universe as a unique system permit many alternative laws?

The relationship of man and the universe has many facets too. Granted that the human being is an observer making and noting measurements of the universe: how does its consciousness relate to this observing process? or the irreversible flow of time that we all experience, does it relate to the large scale dynamics of the universe? Does our own *bhautik* composition tell us about the large scale structure of the universe?

There are several issues that come up in the man-nature-universe triangle. I will briefly highlight a few points in this presentation. My viewpoint is necessarily that of a physicist and astronomer: I lay no claim to scholarship of our ancient heritage. But the scholars may perceive some parallels between what I describe and what has been discussed in ancient times.

The Perfect Cosmological Principle

Let us take the problem of observing and interpreting the universe. As a man at the present epoch observes the distant parts of the universe he sees them not as they are today but as they were a long time in the past. This is because all his observed information has travelled with the speed of light. (at least that is the assumption all scientists start with!). So a galaxy a billion light years ago is seen by him today as it was a billion years ago. How, therefore, does he interpret his observations of such a galaxy?

To make any interpretation he needs a yardstick, viz., the laws of science available to him today. Using these he can estimate how bright the galaxy was, how massive it was and so on. But to what extent is he sure that his yardstick of present times also applied to the remote galaxy a billion years ago? In other words, is he not implicitly assuming that the yardstick of natural laws has remained unchanged over such a long period? This was the question asked by two British physicists — Hermann Bondi and Thomas Gold, two of the three creators of the so-called steady state cosmology in 1948.

The motivation which led Bondi and Gold to the steady state concept sprang from the speculative nature of physics and cosmology in the early post-big-bang era. Theoretical physicists in the 1940s were not willing to speculate about the very early universe. The reason, as Bondi and Gold perceived, was that the physical conditions and the laws governing them in those early epochs would be markedly different from those being studied 'here and now'. Rather than get caught up in untestable speculations, they proposed an alternative scenario which could readily be tested, a scenario which rested on the premise that the overall physical conditions in the universe and the laws governing them do not change at all.

In a sense the Bondi-Gold notion of an unchanging universe is a logical extension of the cosmological principle used by most cosmologists. The cosmological principle states that the state of the universe and the laws of physics influencing it are identical here and elsewhere **at the same cosmic time**. Astronomical observations, on the other hand, tell us about far-away regions in the universe not at the **present** cosmic time, but at **earlier epochs** when the light arriving now left them. So to guarantee a meaningful comparison of observations with theory, we require the universe and its physical laws to be unchanging **with time** as well as space. This is the essence of the 'perfect cosmological principle' (PCP) which led Bondi and Gold to the steady state theory.

An unchanging universe does not necessarily mean a static universe. In fact, in a static, infinitely old universe, physical systems would reach a thermodynamic equilibrium, when the distinction between sources of radiation and their receivers disappears. Every point radiates and absorbs heat in equal quantities. This certainly is not the case with the present universe where we have such powerful radiators of energy as the Sun and the stars and such cool places as the polar caps on the Earth. The alternatives provided by the PCP are either a steadily contracting universe or a steadily expanding universe, of which the former is again ruled out by similar thermodynamical arguments. So we are left with the alternative that the universe has been expanding steadily. Notice that this deduction was arrived at without any dynamical theory like general relativity.

I will not go into technical details but simply state that the deductive power of the PCP also tells us what the space-time geometry of the steady state model should be like. It was emphasized by Bondi and Gold that the PCP combined with local observations of the universe tells us **everything observable** about the universe. Their main stress was on the testability of the PCP, which made unequivocal claims about the large-scale structure of the universe, and was therefore much more vulnerable to observational constraints than the rival big-bang models, which ascribed the bulk of the present observable state of the universe to speculative, very early epochs.

In the end, the strongest observational challenge to the PCP and the steady state

universe came from the discovery of the microwave radiation background. This background must be unchanging, according to the PCP, and it must be continually regenerated as the universe expands. Its origin must therefore be entirely astrophysical in nature. But how can this be? A related problem arose *vis-a-vis* the abundance of light nuclei, especially helium and deuterium. Since there was no hot epoch in the past in the steady state universe (because there is none now), these elements must also be produced continually now. But how? These questions swung the balance of opinion heavily towards the big-bang model in the 1960s.

I will not go into details of how a revival of the steady state concept today is based on the answers to these questions. I present this as an example of man-nature-universe interaction: how the consistency argument requires the universe to conform to what man observes and his interpretation of physical laws.

The Arrow of Time

All living systems 'grow old' in an irreversible way! The biological clock cannot be turned back in real life. Even in our day-to-day perceptions we encounter other phenomena that seems to go only one way. Given two photographs of a china cup, one showing it intact, the other broken to pieces, we can tell which photo was taken **earlier** and which one **later**. A battery driving a wireless transmitter eventually stops working because all its energy has been radiated away. The energy store of the battery steadily diminishes with time.

Why don't we get younger day by day? Why don't broken cups become whole? Why doesn't the transmitter receive energy and charge the battery? These are one-way phenomena which impress upon us the unidirectional nature of the flow of time. The three examples given by me here correspond to three 'arrows' of time: biological, thermodynamic and electrodynamic.

The astronomer can point to a **fourth** arrow of time from his observations of the large scale structure of the universe: the universe is apparently expanding! This discovery was made during the 1920s by E.P. Hubble and M. Humason who found that the spectra of light from galaxies are most invariably 'shifted' towards the red end. This shift is noticed by doing spectroscopy of galaxies, by measuring the wavelengths of certain dark lines in the galactic spectra. These lines seem to appear with wavelengths **longer** than expected. A naive interpretation of this result is that the source of light or the galaxy is moving away from us.

If all galaxies are moving away from one another, it is more appropriate to use the notion of the universe expanding itself! If we took a number of photographs of galaxies at different epochs, we can arrange them chronologically by looking at their separation. At earlier epochs the galaxies will be closer to one another than at later

epochs. Thus we have the **cosmological arrow of time**.

The basic question 'why an arrow?' may be eventually answered. A first step is to understand why all four arrows point the way they do. For example, why don't we grow young in an expanding universe? Why do we see a transmitter lose energy as we grow old and not the other way round?

Again, I shall not go into technical details except to say that some progress has been made in understanding the alignment of the electrodynamic and the cosmological arrows of time. Using certain theoretical formulations one can say why in an expanding universe of a certain kind (like the steady state model just described) an electric transmitter must radiate and not receive energy. This is another example of the man-nature-universe interaction.

The Anthropic Principle

The Copernican revolution was the first step in man's dethronement from the 'centre' of the universe. The steady erosion of man's privileged status reached its ultimate stage in the cosmological principle (or the PCP if the steady state model had turned out to be right). In the homogeneous isotropic universe all galaxies have the same status. Man in his Galaxy is just one of them. Since the trend towards democratization of the universe started with Copernicus, we may call this ultimate concept of cosmic equality the 'Copernican principle'.

A reaction to the Copernican principle, however, was initiated by Robert Dicke in 1961, with the so-called **anthropic principle**. In general terms this principle amounts to the statement that the universe is in the way it is because we are here to observe it. By 'we' is implied the typical human observer who has attained a certain level of intelligence in the course of the evolution of life in the universe. Had the universe been different in its structure and evolution, it would not have been possible for such human observers to evolve to their present stage. This is what the anthropic principle is all about. It is a deductive principle which, one hopes, might narrow the ranges of the parameters in the physical theories and the initial conditions, and lead to a unique model of the universe.

Consider the following application of this principle proposed by Brandon Carter to show how the magnitude of the gravitational constant, G , turns out to be strongly related to our existence. To follow Carter's argument, let us consider the stars which derive their luminosity from nuclear fusion of hydrogen into helium. This process goes on steadily for a considerable period, which constitutes the bulk of the life span of a star. Now in such a state there is a definite relation between the luminosity, L , and surface temperature, T , of a star. In a logarithmic plot of L against $1/T$, such stars lie

on a narrow band called the 'main sequence', which extends from high values of L and T , at the so-called 'blue end', to low values of L and T , at the 'red end' of the sequence, the names corresponding to the dominant colour in the star's radiation.

Now, the crucial parameter which determines where a star is on the main sequence is its gravitational mass. Stars of large mass are at the blue end and are called 'blue giants', whereas those of low mass, 'red dwarfs', are at the red end. So long as the star derives the bulk of its radiated energy from the fusion of hydrogen to helium, it stays on the main sequence. Our Sun is in this state and is located about midway between the red and blue ends. It is also the case that the hydrogen fusion reaction goes fast in high-mass stars and slow in low-mass stars. Red dwarfs therefore take longer to finish off their hydrogen fuel and consequently remain on the main sequence considerably longer than blue giants.

Now consider the origin of life and its evolution to an intellectually advanced state. Suppose that this event occurs on a planet going round a star, and that the energy for sustaining life comes from the star. This evolutionary process requires a certain amount of time as well as sufficient radiation. Blue giants have the radiation but not the time, whereas red dwarfs have the time but not the radiation. The conclusion? That life originates and evolves only around stars which are somewhere in between these two extremities. The sun, lying in this middle region, satisfies these two conditions.

If we now imagine a universe with a considerably larger gravitational constant than the one we actually have, the gravitational masses of all stars in it would be effectively higher. Thus the stars in that universe would tend to be like the blue giants in our universe. Similarly, in a universe with a weaker gravitational constant the stars would be like our red dwarfs. In neither case would life as we know it be possible. Therefore G must take values in a moderately narrow range around its observed value.

The argument as presented about illustrates how the anthropic principle operates. As given here, it is not sharp enough for believers in the principle who would like to demonstrate that values of physical parameters are finely tuned to human existence. Nor is it convincing enough to persuade skeptics who might attack its speculative nature. After all, we still know too little about the formation of planets, about the origin and adaptability of life, about the evolution of intelligence, and so on to be able to conclude definitively 'what would have happened, if . . .'

As for sharpening the Carter-type argument, some progress has been made in bringing other physical constants into the discussion of the anthropic principle — for example, the fine structure constant and constants related to nuclear binding. Of

course, the ultimate success or failure of this line of reasoning must await a deeper understanding of biology.

Biology and Cosmology

The biological considerations peeping out of the anthropic principle may turn out to be the thin end of a wedge. The question 'how probable is the origin of life in the universe?' has cosmological connotations regardless of whether life exists anywhere beyond the Earth because of the possibility of emergence of certain life supporting organic molecules under a favourable environment. What is the chance of such an event occurring by accident? The following argument by Hoyle suggests that the chance may indeed be extremely small.

Enzymes play key roles in the interactions of biological systems with their environment. For example, there are enzymes which are responsible for repairing the damage caused by X-rays and ultraviolet light; there are others responsible for absorption of sugars, for breaking linkages in polysaccharides, and so on. The enzyme, which is made up of a chain of amino-acids, has to be specifically constructed to serve as a catalyst in a particular chemical reaction. In other words, an enzyme is not an arbitrarily chosen chain, like a code word chosen at random from a jumble to convey a significant message.

Even estimated conservatively, each chosen arrangement for a particular enzyme is one among many. For example, as estimated by F.B. Salisbury in 1969, at least fifteen amino-acids must be correctly ordered in a typical enzyme. With twenty alternatives available at each link of the chain, the number of such randomly made chains is 20^{15} , or nearly 10^{20} . The chance of a particular enzyme being made out of such random links is therefore 1 in 10^{20} . Since there are at least 2,000 such enzymes which play key roles in the behaviour of living systems, the chance of arriving at them by a spontaneous accidental process is $10^{-20} \times 10^{-20} \times \dots (2,000 \text{ times}) = 10^{-40,000}$. This absurdly small number according to Hoyle, highlights the improbability of living systems arising purely by accident.

Francis Crick, in his book *Life Itself*, has indulged in a similar game of probability computation. Looking at proteins as vast chains of randomly assembled amino-acids, Crick computes the chance of a 'correct' chain of 200 links emerging this way to be 1 in 20^{200} — that is, about 10^{-260} . Again, the probability of spontaneous emergence of life by chance is far too small, and one wonders if the big-bang universe has had time enough at its disposal to allow such a rare event to take place. The analogies which spring to mind are typified by questions like these: How long will a monkey randomly hitting a typewriter keyboard produce a Shakespearean sonnet by chance? Or how long will be a spontaneous random assembly of component parts, nuts and bolts and

so on, take to produce a jumbo jet?

It could be argued that the computation of the probability of an event after it has occurred can be misleading. It is also arguable that events that seem entirely unconnected and whose probability of occurrence in a given sequence therefore appears to be too small to be realistic may in fact be connected in a way which we do not yet know. There might seem to be a very small probability that the regular arrangements of electrons in atoms came about by chance. Yet the quantum theory of atomic structure fully accounts for those arrangements as natural ones. Likewise, could these low probabilities in biology be unrealistic because we lack an underlying theory?

However one chooses to look upon these low probabilities of spontaneous generation of life, one is driven to the conclusion that biology contains as yet unravelled information which cosmologists may one day find highly relevant to their subject and in future we may find information regarding the origin of living systems to have a bearing on what model we choose to describe the universe. Until such information is forthcoming, our view of the universe, of its present composition and its past history, will necessarily remain incomplete.

Conclusion

In a composition volume devoted to *Prakrti* such issues may find echoes in ancient wisdom. I will be interested to discover how issues of this kind had bothered the truth seekers of the past. As J.B.S. Haldane put it: "The universe is not only queerer than we suppose, it is queerer than we can suppose", implying the inadequacy of the human mind to understand the universe in its entirety. Nevertheless the statement has to be looked at as a challenge to human ingenuity in pushing back the frontiers of the unknown. In that sense my triangle is also expanding!