THE MYSTERIOUS UNIVERSE

By Sir J. Jeans

"The Mysterious Universe" was the subject of the Rede Lecture delivered by Sir James Jeans at Cambridge on Nov. 5, 1930.

The lecturer began with a characteristic figure to express the littleness of our world in space. A few stars were known, he said, which were hardly bigger than the earth, but the majority were so large that hundreds of thousands of earths could be packed inside each and leave room to spare; here and there we came upon a giant star large enough to contain millions of millions of earths. And the total number of stars in the universe was probably something like the total number of grains of sand on all the seashores of the world.

This vast multitude of stars travelled through a universe so spacious that it was an event of almost unimaginable rarity for a star to come anywhere near to another star. For the most part each voyaged in splendid isolation like a ship on an empty ocean. In a scale model in which the stars were ships the average ship would be well over a million miles from its nearest neighbour.

This led Sir James Jeans to a picture of the birth of the solar system. This rare event of a collision took place some 2,000,000,000 years ago.

A second star, wandering blindly through space, happened to come within hailing distance of the sun. Just as the sun and moon raise tides on the earth, so this second star must have raised tides on the surface of the sun. But they would be very different from the puny tides which the small mass of the moon raises in our oceans; a huge tidal wave must have travelled over the surface of the sun, ultimately forming a mountain of prodigious height, which would rise ever higher and higher as the cause of the disturbance came nearer and nearer. And, before the second star began to recede, its tidal pull had become so powerful that this mountain was torn to pieces and threw off small fragments of itself, much as the crest of a wave throws off spray. These small fragments have been circulating around their parent sun ever since. They are the planets, great and small, of which our earth is one. . . .

Gradually the fragments cooled, until now they have but little intrinsic heat left, their warmth being derived almost entirely from the radiation which the sun pours down upon them. In course of time, we know not how, when, or why, one of these cooling fragments gave birth to life. It started in simple organisms whose vital capacities consisted of little beyond reproduction and death. But from these humble beginnings emerged a stream of life which, advancing through ever greater and greater complexity, has culminated in beings whose lives are largely centred in their emotions and ambitions, their æsthetic appreciations, and the religions in which their highest hopes and noblest aspirations lie enshrined.

The Bounds of Life

The rarity of planetary systems, the lecturer argued, had a special significance. Life could exist only inside a narrow zone which surrounded each star at a very definite distance. Outside these zones life would be frozen; inside it would be shrivelled up. At a rough computation, these zones within which life was possible, all added together, constituted less than a thousand million millionth part of the whole of space. And even inside them life must be of very rare occurrence, for it was so unusual an accident for suns to throw off planets as our own sun had done that probably only about one star in 100,000 had a planet revolving round it in the small zone in which life was possible.

Just for this reason (said Sir James) it seems incredible that the universe can have been designed primarily to produce life like our own; had it been so surely we might have expected to find a better proportion between the magnitude of the mechanism and the amount of the product. At first glance at least life seems to be an utterly unimportant by-product; we living things are somehow off the main line. And this impression is only strengthened when we attempt to pass from our origins to an understanding of the purpose of our existence, or to foresee the destiny which fate has in store for our race.

Just as Tantalus, standing in a lake so deep that he only just escaped drowning, was yet destined to die of thirst, so it is the tragedy of our race that it is probably destined to die of cold, while the greater part of the substance of the universe still remains too hot for life to obtain a footing.

Physics told the same story as astronomy. Sir James Jeans pointed to the general physical principle known as the second law of thermo-dynamics, which predicted that there could be but one end to the universe—a "heat-death" in which the total energy of the universe was uniformly distributed and all the substance of the universe was at the same temperature. This temperature would be so low as to make life impossible. It mattered little by what particular road this final state was reached; all roads led to Rome, and the end of the journey could not be other than universal death.

The question, then, "Is this all that life amounts to?" was suggested by astronomy, but it was mainly to physics that we had to turn for an answer. Sir James traced the growth of the purely mechanical interpretation, which received its check, although that was not apparent immediately, in the "quantum-theory."

Perhaps the most startling consequence of the new theory, he continued, was that it appeared, at first sight at least, to dethrone the law of causation from the position it had heretofore held as guiding the course of the natural world. The old science had confidently proclaimed that nature could follow only one road, the road which was mapped out from the beginning of time to its end by the continuous chain of cause and effect; state A was inevitably succeeded by state B. So far the new science has only been able to say that state A may be followed by state B or C or D, or by innumerable other states. It can, it is true, say that B is more likely than C, C than D, and so on; it can even specify the relative probabilities of states B, C and D. But, just because it has to speak in terms of probabilities, it cannot predict with certainty which state will follow which. . . . .

Most mathematical physicists now suppose, at any rate provisionally, that there is no determinism in events in which atoms and electrons are involved singly, and that the apparent determinism in large-scale events is only of a statistical nature. When we are dealing with atoms and electrons in crowds, the mathematical law of average imposes the determinism which physical laws have failed to provide.

To-day we regard the universe as consisting primarily of waves—waves of radiation, whose properties are specified by the undulatory theory of light, and waves of matter, whose nature the new science of "wave-mechanics" is still trying to unravel. Modern physics is pushing the whole universe into one or more ethers. . . . The physical properties of these ethers must be scrutinised with some care, since in them the true nature of the universe must be hidden.

"Probability Waves"

Coming to the theory of relativity, Sir James Jeans describes it as replacing the old mechanical jelly-like ether by a four-dimensional and purely geometrical continuum, in the building of which space and time were inextricably blended. This continuum was not a substance; it was rather a framework, a creation of abstract thought. He used a vivid illustration to show how many physicists regarded the electron-waves as waves of probability:—

When we speak of a tidal wave we mean a material wave of water which wets everything in its path. When we speak of a heat wave we mean something which, although not material, warms up everything in its path. But when the evening papers speak of a suicide wave they do not mean that each person in the path of the wave will commit suicide; they merely mean that the likelihood of his doing so is increased. If a suicide wave passes over London the death-rate from suicide goes up; if it passes over Robinson Crusoe's island the probability that the sole inhabitant will kill himself goes up. The waves which represent an electron in the wave mechanics may, it is suggested, be probability waves, whose intensity at any point measures the probability of the electron being at that point. . . .

Another drastic possibility arising out of a suggestion made by Bohr is that the minutest phenomena of nature do not admit of representation in the space-time framework at all. . . . It is conceivable that happenings entirely outside the continuum determine what we describe as the "course of events" inside the continuum, and that the indeterminacy which present-day physics attributes to nature may arise merely from our trying to force happenings which occur in many dimensions into a smaller number of dimensions.

Imagine, for instance, a race of blind-worms, whose perceptions were limited to the two-dimensional surface of the earth. Now and then spots of the earth would sporadically become wet. We, whose faculties range through three dimensions of space, call the phenomenon a rain-shower, and know that events in the third dimension of space determine, absolutely and uniquely, which spots shall become wet and which shall remain dry. But if the worms, unconscious even of the existence of the third dimension of space, tried to thrust all nature into their two-dimensional framework, they would be unable to discover any determinism in the distribution of wet and dry spots; the worm-scientists would only be able to discuss the wetness and dryness of minute areas in terms of probabilities, which they would be tempted to treat as ultimate truth.

Although the time is not yet ripe for a decision, this seems to me, personally, the most promising interpretation of the situation. Just as the shadows on a wall form the projection of a three-dimensional reality into two dimensions, so the phenomena of the space-time continuum are four-dimensional projections of realities which occupy more than four dimensions.

Shadows of Reality

The general recognition that we were not yet in contact with ultimate reality was, from the broad philosophical standpoint, Sir James Jeans argued, the outstanding achievement of twentieth-century physics.

To speak in terms of Plato's well-known simile, we are still imprisoned in our cave, with our backs to the light, and can only watch the shadows on the wall. At present the only task immediately before science is to study these shadows, to classify them and explain them in the simplest possible way. And what we are finding, in a whole torrent of surprising new knowledge, is that the way which explains them more clearly, more fully, and more naturally than any other is the mathematical way, the explanation in terms of mathematical concepts. . . .

The shadows which reality throws on to the wall of our cave might *a priori* have been of many kinds. They might conceivably have been perfectly meaningless to us, as meaningless as a cinematograph film showing the growth of microscopic tissues would be to a dog who had strayed into a lecture-room by mistake. Indeed, our earth is so infinitesimal in comparison with the whole universe that it is *a priori* all too probable that any meaning that the universe as a whole may have would entirely transcend our terrestrial experience, and so be totally unintelligible to us.

But it was not impossible that some of the shadows might suggest objects and operations. Indeed, nature seemed very conversant with the rules of pure mathematics, as they had been formulated in the studies of the mathematicians.

It is difficult to discuss the nature of the reality behind the shadows; we have no extraneous standards against which to compare them. For this reason it is probable, to borrow Locke's phrase, that "the real essence of substances" is for ever unknowable. We can only progress by discussing the laws which govern the changes of substances and so produce the phenomena of the external world. And a scientific study of the action of these laws suggests a conclusion which may be summed up, though very crudely and quite inadequately. . . . The universe does not appear to work, as was at one time thought, on animalistic or anthropomorphic lines, nor, as was recently thought, on mechanical lines ; it rather works on purely mathematical lines. In brief, the universe appears to have been designed by a pure mathematician. . . .

It would now seem to be beyond dispute that in some way nature is more closely allied to the concepts of pure mathematics than to those of biology or of engineering, and even if the mathematical interpretation is only a third man-made mould, it at least fits nature incomparably better than the two previously tried. . . .

If the more intricate concepts of pure mathematics have been transplanted from the workings of nature, they must have been buried very deep indeed in our sub-conscious minds. . . . . The terrestrial pure mathematician does not concern himself with material substance but with pure thought. His creations are not only created by thought but consist of thought, just as the creations of the engineer consist of engines. And the concepts which now prove to be fundamental to our understanding of nature—a space which is finite; a space which is empty, so that one point differs from another solely in the properties of the space itself; four-dimensional, seven and more dimensional spaces; a space which for ever expands; a sequence of events which follows the laws of probability instead of the law of causation—or, alternatively a sequence of events which can only be fully and consistently described by going outside space and time—all these concepts seem to my mind to be structures of pure thought, incapable of realisation in any sense which would ordinarily be described as material.

A Universe of Thought

To these I would add other more technical concepts, typified by the "exclusion principle," which seems to imply a sort of "action-at-a-distance" in both space and time—as though every bit of the universe knew what other distant bits were doing and acted accordingly. To my mind, the laws which nature obeys are less suggestive of those which a machine obeys in its motion than of those which a musician obeys in writing a fugue, or a pcet in composing a sonnet. The motions of electrons and atoms do not resemble those of the parts of a locomotive so much as those of the dancers in a cotillion. And if the "true essence of substances" is for ever unknowable, it does not matter whether the cotillion is danced at a ball in real life, or on a cinematograph screen, or in a story of Boccaccio. If all this is so, then the universe can be best pictured, although still very imperfectly and inadequately, as consisting of pure thought, the thought of what, for want of a wider word, we must describe as a mathematical thinker.

By a very different road modern science seems to me to lead to a philosophy very similar to that which Bishop Berkeley summed up in the words: "All the choir of heaven and furniture of earth, in a word all those bodies which compose the mighty frame of the world, have not any substance without the mind. . . . So long as they are not actually perceived by me, or do not exist in my mind, or that of any other created spirit, they must either have no existence at all, or else subsist in the mind of some Eternal Spirit."

This concept of the universe as a world of pure thought implies of course that the final truth about phenomenon resides in the mathematical description of it; so long as there is no imperfection in this our knowledge of the phencmenon is ccmplete. We go beyond the mathematical formula at our own risk; we may find a model or picture which helps us to understand it, but we have no right to expect this, and our failure to find such a model or picture need not indicate that either our reasoning or our knowledge is at fault. . . .

This point of view brings us relief from many of the difficulties and apparent inconsistencies of present-day physics. We need no longer discuss whether light consists of particles or waves; we know all there is to be known about it if we have found a mathematical formula which accurately describes its behaviour, and we can think of it as either particles or waves according to our mood and the convenience of the moment.

While it could not be claimed that any of our new physical knowledge was final, Sir James thought it safe to say that the river of knowledge had made a sharp bend in the last few years.

To-day there is a wide measure of agreement, which on the physical side of science approaches almost to unanimity, that the stream of knowledge is heading towards a non-mechanical reality; the universe begins to look more like a great thought than like a great machine. Mind no longer appears as an accidental intruder into the realm of matter; we are beginning to suspect that we ought rather to hail it as the creator and governor of the realm of matter—not, of course, our individual minds, but the mind in which the atoms out of which our individual minds have grown exist as thoughts. . . .

We discover that the universe shows evidence of a designing or controlling power that has something in common with our own individual minds—not so far as we have discovered, emotion, morality, or æsthetic appreciation, but the tendency to think in the way which, for the want of a better word, we describe as mathematical. And while much in it may be hostile to the material appendages of life, much also is akin to the fundamental activities of life; we are not so much strangers or intruders in the universe as we at first thought. Those inert atoms in the primeval slime which first began to foreshadow the attributes of life were putting themselves more, and not less, in accord with the fundamental nature of the universe.—(*The Times*).