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760TH ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL, WESTMINSTER, S.W.1. ON MONDAY, JUNE 6TH, 1932,

AT 4.30 P.M.

DR. JAMES W. THIRTLE, M.R.A.S., IN THE CHAIR.

The Minutes of the last Meeting were read, confirmed, and signed.

The CHAIRMAN then called on Sir Ambrose Fleming, D.Sc., F.R.S., the President, to give the Annual Address on "Some Recent Scientific Discoveries and Theories."

ANNUAL ADDRESS.

SOME RECENT SCIENTIFIC DISCOVERIES AND THEORIES.

By SIR AMBROSE FLEMING, F.R.S. (*President*).

I.

IT is not an unprofitable occupation to take stock from time to time of the intellectual position of civilized mankind in certain matters, and to endeavour to obtain a broad view of the achievements and tendencies of current thought in various regions of inquiry.

Our present age is pre-eminently a scientific one. The ingenuity of the human mind has enabled us to devise innumerable instruments which vastly extend the range and power of the human organs of sense. Some of these appliances enable us to detect and measure physical agencies such as magnetic fields or electromagnetic waves which do not affect directly any of our senses.

In some instances we have obtained means of seeing objects which never have been seen, nor indeed can be seen, by the unassisted human vision, as when a photographic plate is used in the focus of a telescope or microscope of suitable construction.

We have been able to invent instruments such as the Spectroscope which enable us to determine the motion of near or far-distant objects which do not seem to move, and means for determining the distance of stars so remote that light takes millions of years to come to us from them, even though it travels at the rate of 186,000 miles a second.

The outcome of all this recent research has been popularized, and has given us of late years a view of the physical Universe which in grandeur and immensity amounts to a new revelation. Therefore it is important to obtain some general impression of the result of it all on the average human mind.

Hence in this Annual Address I thought I might attempt the task of giving a brief epitome of some of the more recent results of this scientific investigation in the departments of Astronomy and Physics, and of the conclusions or theories that have been built upon them. As time is limited, I shall only be able to give brief sketches of the advances under about four different heads as follows:—

1. Advances in our general knowledge of the physical Cosmos, that is of the stellar Universe generally.
2. Discoveries with regard to Radiation of which what we call Light is only a very limited portion.
3. Progress in knowledge concerning the ultimate nature of Matter.
4. Investigations respecting Gravitation and its connection with other physical Agencies.

II.

We may notice, in the first place, that the mere collection of new facts by observation or experiment is not the chief aim of scientific investigation, although it is a necessary foundation for it. The human mind craves above all for what we call explanations of phenomena, or means for regarding them as the result of some ascertained general principle or necessary consequences of other known phenomena. Our fundamental idea of causation makes us desire to see the relation of cause and effect established in as many cases as possible, for isolated and

unconnected observations or facts are unsatisfactory to our minds. Accordingly, we are prone in all cases, when brought face to face with new or common facts of observation, to devise what we call explanations of them, or to endeavour to see them as the necessary consequences of some general principle, or generalization. We construct our scientific theories or hypotheses to meet these requirements. But it is always necessary to bear in mind that even if we can imagine some mechanism capable of producing a result we see in Nature, it does not in the least follow that it is actually done in that way. Moreover, an explanation may seem perfectly valid when based on a certain limited range of observed facts, but may fail totally to account for other facts which may subsequently be discovered.

Hence our scientific theories or hypotheses are in a continual state of flux, and that which is cherished to-day may have to be abandoned to-morrow. In the popularized accounts of scientific investigations this vital distinction between the ascertained facts and the non-permanent explanations of them is not always held well in view. The result is that the general public are apt to mistake the hypotheses or theories for scientific knowledge, and may fail to remember that whilst the well-ascertained results of observation or experiment remain as solid achievements built into the fabric of certain knowledge, the speculations or theories are often short-lived products of the mind of man which occupy the attention for a time and then pass away.

III.

Turning then, however, to the matters of fact we consider as ascertained, we may note, first:—

1.—The Advances in our Knowledge of the Structure of the Stellar Universe.

In this department of scientific research the progress has been chiefly due to the construction of immense telescopes, both refractors and reflectors, and their use in conjunction with dry-plate photography in especially clear atmospheres abroad.

The three great problems to the solution of which attention has been directed are (1) The Nature, (2) The Distance, and (3) The Arrangement, or distribution in space, of all the stars we see in the sky at night.

As regards (1) the upshot of research has been to show that the stars may be divided into three chief groups. There are, first, a small group called the Red Giants. These are merely immense masses of rarified gas. They are red because they are only at a temperature of red heat at the surface, but perhaps one or two million degrees in the centre.

These stars are of enormous size, and their diameters in a few cases have been measured by an instrument called an Interferometer. They are large enough to contain, not only our sun and the earth's orbit as well, but even up to the orbit of the planet Mars. An example of a Red Giant is the star Betelgeuse in the constellation of Orion. These Red Giants are not numerous, and there are none in proximity to our Sun.

In the next place, there are a small number of relatively small stars called White Dwarfs. These are white because they are intensely hot at a white heat on the surface, and are so dense in structure that a mere handful of their material would on our earth weigh many tons. They have enormous temperatures at their centres. A White Dwarf the size of the earth may contain 10,000 times the mass or matter of it. The third and by far most numerous class of stars, comprising 80 per cent. of all, are called Main Sequence stars, of which our Sun is one. They vary greatly in size and brilliancy, and temperature, and therefore in surface colour, from large blue hot stars to small red and cooler stars.

Then as regards distance and methods of measuring it. There are three ways in which we can plumb the depths of space and find the stellar distances.

The first method is by ordinary surveying. When a surveyor wishes to find the distance of some inaccessible object, he marks off on the ground a measured base line, and observes at each end the angle between this base and the bee-line to the object. Then a simple calculation gives him the distance to it. For certain near stars the same procedure can be followed. The base line, however, is the diameter of the earth's orbit, which is 186 million miles, and the observations are made by photographing the same group of stars at six months' interval. Then, by very exact measurements on the plates, it is possible to determine what is called a star's parallax, or the angle subtended by the earth's orbital radius at the star, and hence its distance.

Perhaps about 100 or more stars have had their distance determined in this manner. These distances are expressed in

Light-Years, a light-year being equal to six million million miles, which light would travel in one year.

The nearest star is called *Proxima Centauri*, and is about $4\frac{1}{4}$ light-years distant. To realize what this means, place a good-sized orange, to represent our Sun, at one end of a long room, and 30 feet away put a small fig-seed, which will represent the earth; then to denote the nearest star, we must place another orange 1,500 miles away. Such is the scale on which the Universe is constructed. A second method for determining the stellar distances depends on the fact that there are certain stars similar to one in the constellation of Cepheus which wax and wane in brightness. It has been found that there is a definite relation between the time-period of variation and the absolute brightness or candle power of these short-period variables. The distance of some of them has been measured by the surveyor's method, and hence their absolute brightness is known.

Now we can easily measure the apparent brightness of stars, and this is measured by the absolute brightness or candle power, divided by the square of the distance of the star. We can tell from the periodic time of the variable stars their absolute brightness, and hence determine its distance. The star called Delta Cephei has a period of $5\frac{1}{3}$ days, and stars like his occur in all parts of the sky. This star emits 600 times the light and heat given by our Sun. If, then, we find a Cepheid variable mixed up with other stars, and if we measure its apparent brightness, we can tell at once its distance from us. In this manner the distance of many star clusters and nebulæ have been determined.

There is a third method of finding the absolute brightness or candle power of a star from its spectrum, and the relative strength or intensity of certain lines in this spectrum, but it would occupy too much time to go into details. The method of sounding the depths of space by Cepheid variable stars is of the utmost importance, because whilst the surveyor's method is not possible for greater distances than about 100 light-years, there is no limit to the use of the Cepheid method.

The general result of all this work has been to show that all the stars we can see with the naked eye, or with a telescope of moderate power, are arranged over a space in the form of a flat circular disk of biscuit or watch-shape called the Galactic area or system. Its greatest diameter is about 220,000 light-years and its thickness perhaps about $\frac{1}{5}$ or 40,000 light-years.

Our Sun is a member of a smaller collection of stars contained within the Galactic area, but not at its centre. The whole Galactic area has been estimated to contain about 30,000 million stars. The faint nebulosity we see across the night sky, which extends right round the sky called the Milky Way, is simply the crowd of indistinguishable stars on the periphery or edge of the Galaxy. Scattered about in this area there are also about 100 so-called globular clusters of stars, each containing many thousands of stars; the nearest of these is about 18,000 light-years distance, and the farthest about 185,000 light-years. Sir Arthur Eddington has shown that this Galaxy rotates round a central point probably in 250 million years.

In addition, there are some hundreds of so-called planetary nebulæ in the Galactic area, which may be stars surrounded with a garment of luminous haze. Also there are irregular wisps of gaseous matter or dust, some of which are luminous and some are dark.

Recent research with the large telescopes in America has shown that far outside this Galactic system there lie "Island Universes," of vast size and spiral form, which are masses of gas, condensing or condensed into stars. They lie at distances (from us) of 1 to 140 million light-years, and some two million of them are within range of the Mount Wilson 100-inch reflector telescope. Our Galaxy is probably one of the largest of these separate Universes of stars.

These immense and separate galaxies of stars are in rotation. The most astonishing observation about them, however, is that they are most of them apparently running away from us, with stupendous speeds, from 1,000 to 15,000 miles a second. The question is not yet settled whether these speeds, as determined by the shift of spectral lines, are due to an actual motion of recession, or due to some other cause. If it is real, then the Universe is expanding at an inconceivable rate.

IV.

Leaving, however, for the moment these question of theory, we pass on to notice:—

2.—Discoveries with Regard to Radiation.

We know that Light takes time to pass through space, and that it conveys energy. Mark off a square area on the ground,

each side of which is 8 yards, and suppose brilliant tropical sunshine to fall vertically on it. If we could collect all the heat and light then incident on it, and use it, it would work a 100 horse power engine. All this energy comes out of the Sun, and travels to us at the rate of 186,000 miles per second.

Whilst the Light is travelling to us, it is called Radiant Energy. In this radiant energy something oscillates very rapidly, and the number of oscillations or vibrations per second is called the *frequency*.

Also at certain intervals of space called a *wave-length* the same sort of change is taking place at the same instant. If one vibration has twice the frequency of another, they are said to differ by 1 octave. We are acquainted with 60 or 70 octaves of radiation. The waves which produce the sensation of light in our eyes lie within 1 octave; the average wave-length of which is $\frac{1}{50000}$ part of an inch, and average frequencies is 600 billion. The waves mostly used in wireless broadcasting are about 300–400 metres in wave-length, or about 600 million times as long as light-waves. There are certain very short waves called Cosmic Rays, which come to us from distant parts of the Universe, which have a wave-length as much shorter than light-waves as light-waves are shorter than wireless-waves.

These Cosmic rays are so penetrating that they will pass through 16 feet of lead or 200 feet of water, whereas the thinest film of gold-leaf stops all light. Between the light and the Cosmic rays lie the ultra violet and the radium rays, now so much used in medicine.

The impulse which starts these oscillations is when an electron, which is an ultimate atom of negative electricity, has its motion arrested or changed.

The difference between the energy of the electron before and after that event is shed off as radiation. The remarkable thing, however, is that the frequency of this radiation is always such that its numerical value, multiplied by a certain constant called after its discoverer Planck's Constant, is equal to the difference of the electron energy before and after the change or collision. The product of the frequency and the Planck Constant is called 1 Quantum.

For this reason the X-rays and Cosmic rays—which have vastly greater frequency, the latter nearly 500 million times that of visible light—can exert such destructive action. The Cosmic rays destroy every second about 20 atoms per cubic

inch in the atmosphere, and millions of atoms per second in our human bodies. Whether this is helping to keep us alive, or hastening our decease, we do not know.

V.

We must then pass on to notice

3.—Progress in our Knowledge Concerning the Ultimate Nature of Matter.

The idea that the chemical atom of matter was a small solid bit of matter, which could not be broken or divided, was destroyed in the closing years of the last century, when Sir J. J. Thomson proved experimentally that from atoms of all kinds we extract still smaller atoms, which were found to be atoms of negative electricity. Then Rutherford's discovery of the nucleus, and Thomson's of the proton, gave us the astronomical theory of the atom, that in it a collection of planetary electrons revolve round a nucleus built up of protons and electrons, compacted into a mass vastly smaller than the over-all size of the atom.

Thus for instance the atom of Hydrogen gas consists of the proton with the electron revolving round it at various distances. This orbital distance may be 100,000 times or more the diameter of an electron or a proton.

In other atoms the nucleus is a more complicated structure of protons and electrons, with a group of electrons revolving round it at various distances. An atom is therefore a very open or transparent structure, and might be said to resemble the case of a few dozen gnats buzzing round a grain of sand in a space the size of Westminster Abbey or St. Paul's Cathedral. Quite recently at Cambridge it has been proved that it is possible to have a structure called a *neutron*, consisting of a proton and an electron, so close together that the electric charges neutralize each other, and this small particle, possibly about one-tenth of a billionth of a centimetre in diameter, has no electric charge at all. It can therefore pass freely through other atoms.

This astronomical theory of atomic structure has been supported by, and suggested, much valuable research, but it has been found to fail to give a full interpretation of the spectra. Moreover, the extremely important discovery has been made

lately, that an electron and also a proton behave sometimes as if they were a system of waves, and not as mere particles.

Just as we formerly thought of the atom as an indivisible particle, so when that idea was found to be erroneous we still thought of the electrons as particles. But now, we have to abandon that idea also. It has been proved, by the work of G. P. Thomson, Davisson and Germer, Rupp and Dauvillier, that when a narrow stream of electrons either passes through a very thin sheet of metal, only a few atoms thick, or else is reflected from the surface of a smooth crystal of nickel, on a photographic plate, then a diffraction pattern is obtained similar to that which would be found if for the stream of electrons we were to substitute a slender beam of X-ray Radiation. This proves that, associated with the electron is a set of waves, or else the electron itself is only a group of waves. The same is true of the proton, as proved by Prof. A. J. Dempster of Chicago.

Hence all matter may be only a set of waves, and this indicates that what we call Radiation, and what we call matter may after all be only different aspects of the same ultimate entity.

VI.

4.—Investigations Respecting Gravitation and its Connection with other Physical Agencies.

Newton laid the foundations of exact astronomy by his enunciation of his famous law of gravitation, namely that every atom of matter attracts every other atom with a force which varies inversely as the square of the distance. Hence Newton considered that atoms pull one another together. There are two facts, however, which are important. The first is that the action of gravity is instantaneous. Light, heat, and electric force are propagated or act through space, but they occupy time in travelling. Again, if an atom can act on another atom at a distance, in what manner is this action transmitted? The validity of Newton's law is confirmed by the fact that it enables us to predict astronomical events such as eclipses which happen in accordance with the prediction. Then again, no one has yet been able to find any relation between the force of gravitation and other physical forces of attraction or repulsion.

Gravitation, then, is something unique, and Einstein was the first to point out that a limited gravitation field can be exactly

imitated by an inertial field. To understand this imagine a weight of 1 lb. hung by a spring balance from the ceiling of a lift. If the lift were moving uniformly up or down, then after the first start the spring balance would record correctly, a weight of 1 lb. If, however, the lift were moving up or down with an accelerated motion, then the spring balance would record an increase or diminution in the weight, just as if gravity had been increased or diminished. It can be proved from this fact that a ray of Light should be bent on passing near a heavy mass of matter. This was found to be the case of observations made on May 29th, 1919, at Sobral in North Brazil, and at Principe in the Gulf of Guinea, on the occasion of the total Solar Eclipse on that date. Thus Einstein's prediction of the bending of a ray of light round the Sun was substantially fulfilled.

Einstein has also enunciated a broad general principle, which has been confirmed by its consequences. It is that all laws of Nature must be stated in such a form that they are equally true for all observers. This shows that Newton's law of gravitation cannot be absolutely exact, because when we say the force is inversely as the square of the distance, the question arises, distance measured by what observer? Einstein has given an exact law of gravitation, which has been confirmed by its ability to explain a certain anomaly in the motion of the orbit of the planet Mercury, which Newton's law could not explain.

Nevertheless Newton's law is substantially exact, and the difference between the two laws is very slight.

VII.

5.—General Trend of Scientific Thought.

Broadly speaking, we may say that the general trend of Scientific thought at present (1932) is toward certain conclusions as follows:—

1. We are by no means so certain as were our predecessors in the middle or the third quarter of the 19th century that we have reached finality in our investigations of Nature or that it is entirely comprehensible by our minds. On the contrary, matters that seemed plain to them are very obscure to us.

2. There is a very much stronger conviction now that ultimate or final causes are beyond reach of the human intellect and that our scientific theories are as it were but transient pictures we make of the supposed mechanism of the Universe based on imperfect knowledge of it which may be useful up to a certain point but have to be then discarded and replaced by others.
3. There is in the minds of many scientific workers a strong sense that there are evidences of purpose and design in natural phenomena, which are not the result of chance, but indicate teleological aims, though at the same time there is much which seems to us at present purposeless and meaningless. The quantitative or numerical aspects of multitudes of phenomena suggest that the physical Universe is not so much a Thing as a Thought and Thought implies a Thinker.
4. There are unquestionable evidences that the material Universe had a beginning in the sense that it has not endured in its present form for an infinite past nor can it be the result of a chance development, though our modern investigations have enormously enhanced our ideas of its age and size.
5. There seems to be proof that the physical Universe is not in itself eternally enduring, but is as it were wasting away and moving towards a state in which some fresh act of creation will be required if physical phenomena as we know them are to continue. It is not therefore self-produced or self-maintained, but the result of a Creative Power, and requires a continually operative Directive Agency.
6. There is a considerable body of opinion that the word Evolution may be used legitimately to describe the *process* of gradual changes in phenomena or things advancing from simplicity to complication, but its use as a term to connote a self-acting impersonal causative or *Creative Agency* is unphilosophical; for the reason that such use attributes to a mere impersonal abstract idea of increasing perfection the powers and qualities found only in association with a self-conscious personal Mind or Intelligence. There are unquestionably in the physical Universe things that stimulate our appreciation of Order, Beauty, Adaptation, Numerical Relations and

Purpose in our minds, who are thinking, feeling persons, and hence the qualities which excite these psychic reactions must have been bestowed on the Universe by a Sentient Intelligence at least as personal as ourselves.

7. Another very significant change in scientific opinion is the altered view as regards physical determinism. The 19th century held the opinion that the state of the Universe at any moment was rigidly determined by its previous states. There was as it were an inflexible causality or "reign of unbroken law." The modern introduction of the Principle of Indeterminism in Physics has shown us that it is impossible to define precisely the physical state of any material system, and all that can be said is that one sequence may be more probable than another. This principle has not only invalidated former statements as to the inviolability of so-called natural law but extended into the region of psychology has cut the ground from under some of the old arguments against the possibility of Free Will in rational man.
8. There is a by no means negligible conviction that the phenomena of life cannot be wholly explained by atomic mechanism but involves some factor which is non-material or perhaps we should say super-material.

At the same time it is necessary to note that much of the instruction put forth in the daily press, magazines, and popular books on the subject of Science is uncritical, and often accepts half baked scientific hypotheses as scientific knowledge. There is a widespread effort to discard definite belief in creation by adherence to a vague doctrine of Evolution which has no solid basis of proof.

This is seen particularly in connection with some popular teaching on the subjects of biology and anthropology. Confident statements on the evolution of humanity from the animal races and the enormous age, even to millions of years, over which this development by natural selection has extended are put forward for public acceptance as facts, whilst no sufficient evidence for them is vouchsafed. At the same time it is difficult to secure attention to, or publication for, the arguments or facts opposing these conclusions. Hence there is abundant room and indeed necessity for such a Society as the Victoria Institute

which affords a platform on which can be discussed questions lying on the borderlands of Science, Philosophy, and Religion.

None of the other existing Societies have exactly the same *métier*, and it would be a serious loss if our activities were limited or arrested by insufficient public support. Looking back on the papers read during the present session, I think they will not be found to be of less interest than any of those read in our past 65 years. Our aim is to endeavour to reach on questions in dispute reasonable certainty on the side of truth, or at least to clear away the mists of unconfirmed hypotheses or erroneous assumptions and justify our motto, *Ad majorem Dei gloriam* ("To the Greater Glory of God").

On the call of the CHAIRMAN a hearty vote of thanks was accorded to Sir Ambrose for his address.