April 30: 1956

THE STRUCTURE OF THE UNIVERSE

Address to the Eastern Chapter of Credit Unions nheld in the hall of the Woodside-Imperoyal United Churhc.

The Structure of the Universe :

Credit Unions: Dartmouth N.S. April 30, 1956

Speculations about the structure of the universe are almost as old as human thought.-

They date from the time when men wondered why the sun rose and set, why the moon waxed and waned, why the panorama of the night sky changed with the hours, and the days and the seasons.-

But modern theories date only from the year 1917 when there appeared Einstein's paper entitled "Cosmological Considerations in General Relativity Theory". That was two years after Einstein had first announced his General Relativistic Theory.

The problem which set Einstein on the road to fame was the problem of the want of harmony between pure and applied mathematics.-

When Einstein was a student at the Polytechnic School at Zurich, he had seen great mathematicians formulate most beautiful theories which promised to be of no practical use to any man at any time.- On the other hand there were physicists looking for mathematicians who could help them solve some of their unsolved problems, and they could find none.-

There seemed to be a gap between the idealistic world of the mathematicians and the real world of the physicist.

Einstein's attempt to bridge this gap lead to his theory of relativity.

His Special Theory (announced in 1905) was relatively simple. It simply substituted relative time for absolute time.

His General Theory, of 1915, was more complex, but no more original.

He merely welded together already existing, but disparate ideas.

Using Riemann's (†1866) four-dimensional geometry (of 1854) and ~~Minkowski~~ Minkowski's concept of space time he confected a composite geometry which he was able to apply to the physical world by identifying Riemann's points with events in space-time.

One of the results of Einstein's procedure was the nature of space, for any material system depended upon properties and behavior and distribution of the masses in it.-

If there were no masses, there was no space.- If the masses were at rest, there was Euclidean, three-dimensional space.-

If the masses were accelerated, they moved in a curved space, — the shape of which depend on the energy, density and momentum of the masses.-

His paper, on Cosmology, in 1917

~~His paper of 1917~~ was an attempt to illustrate his theory by applying it to the universe as a whole. - He had to consider the properties of the masses in it. -

The momentum, pressure, temperature and internal stresses of a star are astronomical in amount. - For Einstein's purpose, it was sufficient to consider them very, very large.

The question of density, or distribution of matter, presented a problem. Einstein assumed ~~suggested~~ that it probably did not vary significantly throughout the universe (- he was then thinking of the number of stars per given cubic volume). - So he worked out his problem for a universe of uniform density, and found that it would be finite in extent [but unbounded], - a closed ~~system - so he worked out his problem for a universe of uniform density, and found~~ ~~with curved space.~~ systems, — and (- as he had expected -) with curved space

It was in Berlin, and during World War I, that Einstein worked out his Cosmological Theory.-

The ring of steel around Germany did not prevent news of science coming through.-

It was through Holland that England received news of Einstein's work.- Willem de Sitter, professor of astronomy at Leiden, who had agent both in Berlin and in London, wrote a paper on Einstein's theories for the Royal astronomical Society (Mon. Not. R.A.S. 78, 3. (1917).-

Sir Arthur Eddington, at Cambridge, became an ardent relativist.-

1927

After the 1914-18 war, a young Belgeian priest, abbé Le Maitre, went to England, to Cambridge, to study under Eddington.- He became a great Einstein fan.- But, on his return to Belgium, he began wondering what would happen if ~~then~~ an explosion took place in Einstein's universe.- He worked out, according to Einstein's principles, that an explosion, even on our planet, would disturb the equilibrium.- He went on further to show that Einstein's universe would not be stable, it would be continually expanding.-

He published his paper in a learned journal in Belgium in 1927. His views gained no notice until Eddington had read it, and called Einstein's attention to it.

Einstein read Le Maitre's paper.- Like a contented cat, he purred with pleasure as he read equation after equation by one who seemed to know his relativity.- When he came to the conclusion: either "there is a flaw in Einstein's theory" or "the Universe is expanding", he said: "The Universe is expanding," and his pronouncement made the headlines.-

So much for Cosmology, which is a priori theory.- for the present.

Either Einstein's mass-energy relation is not valid with Universe is Expanding

Let us now look at the astronomical facts:

In 1917, the largest telescopes in operation were the 61" reflector at Harvard (1900) and the 60" at Mount Wilson (1908).

These showed our galaxy as a collection of stars with interstellar nebulae. Outside of our galaxy there seemed to be nothing but nebulae.

Einstein's concept of the universe was of our galaxy surrounded by nebulae, — nebulae which did not seem to matter in the over-all picture. -

By 1908 Dreyer had indexed 13,000 objects as "clusters or nebulae" all but a few hundred of which were nebulae (either galactic or extra-galactic).
(RDS. #889 p 817
#859 p 791)

In 1919, the 100" telescope on Mount Wilson came into operation.

In 1924, the Director of Mt Wilson Observatory, Walter S. Adams was able to announce that the 100" telescope had resolved so many of the spiral nebulae into stars, that these could be classed as "island universes" [as Kant von Herschel had suggested in 1786].

In 1927, Edwin Hubble estimated the distance of the brightest of these to be nearly a million light-years, - which in those days was considered fantastic. - The greatest distance ~~of that~~ previously known was the diameter of our own galaxy, 100,000 light-years.

There was reason to believe that all the "island universes" or exterior galaxies were roughly about the same size, - more or less the size of our galaxy, with its 100,000 million stars. -

Consequently those which looked faintest were adjuged to be farther away. -

This was about the state of affairs in 1929, when Mount Wilson was asked:- "What have you to say about Einsteins theory of an expanding universe?"

Mount Wilson was able to say that all the more distant galaxies seemed to be receding.

Not only that, but Hubble had now measured the distances of many ~~of the~~ galaxies, and found that for the more distant ones their ~~velocities~~ distances varied directly as their rates of recession [which had been measured, before 1919, by V.M. Slipher]*

$$r = \frac{V}{H}$$

H: Hubble's constant (1929).

This was taken to be observational evedence of an expanding universe, and there was great excitement.-

But it was not ~~so simple~~ quite so simple,- as far as Mt Wilson was concerned,- for the nearer ~~stellar~~ galaxies did not seem to be receding.

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* NGM reports rates ~~from~~ as 1919

Einstein was invited to the U.S., and came in 1930 as visiting professor to Cal. Inst. of Tech.-

He found astronomers thinking of the universe as composed of galaxies, like islands in space, and of each one as being composed of thousands of millions of stars.-

An adjustment had to be made in his cosmological theory.- The galaxies became the units of the system.-

The rates of recession of the more distant galaxies was so great that the motions of individual stars became insignificant, as did also the vagaries of the nearer galaxies.-

While Einstein was in California, LeMaitre was invited to Harvard, where spent a year. ~~Today~~

He and Einstein were agreed that the observable universe could be explained by Relativity theory.-

But LeMaitre was interested in the beginning of things, and thought up a theory which has weathered well amidst storms of controversy.-

In 1931, he wrote a paper for the Royal Astronomical Society, pointing out how the Universe might have been created as a dense, very dense, solid homogeneous mass, conforming to the conditions of Einstein's static universe. Then a sudden release of its nuclear energy would be sufficient to blow it apart and set the galaxies.- At that time there was no experimental evidence of nuclear energy, but LeMaitre took ~~it~~ for granted it existence because he accepted Einstein's famous equation which shows the ~~possibility~~ relationship between mass and energy.-

It was Eddington who introduced LeMaitre to the Royal Astronomical Society.- He admired LeMaitre genius and ability, but he did not like his theory.- He referred to it as "LeMaitre's fireworks theory".-

He preferred to think that the beginning of the universe was a nebula, from which galaxies were formed by condensation.

Eddington's theory lost favour as it was found that the slow rate of formation of stars would lead to a greater difference in age between the oldest and the youngest than astrophysicists were ready to admit.-

As a professor at Cambridge, Eddington had an influence on succeeding generations at Cambridge, and the Cambridge school is still tinged with some of his ideas.-

To me, it seems that Eddington's objection to Le Maitre's universe was largely sentimental- as is, certainly, the objection of the present Cambridge school.-

Eddington argued that if the universe started flying apart, as Le Maitre suggested, it would be losing energy all the time.- Its entropy would increase.- It would some day die of cold.- This left him almost disconsolate.- The fact that it would not perish for hundreds of thousands of millions of years brought him no comfort or consolation.-

as I am convinced that it will some day cease to be, I think that for it to run down would be as good a way as any,- and better than some.-

In the period from 1930 & 1936, what was expanding most was the amount of literature on the expanding universe.-

The amount that was written on the expanding universe was growing greater day by day, like a baloon being blown up, until Hubble, of Mount Wilson, stuck a pin in it, and it collapsed.

In 1936, Hubble wrote a paper for the Astr. Journ (84, 517), and (according to the fashion of the time) later (1937) expanded it into a popular book entitled:

"The Observational approach to Cosmology".-

He pointed out:

(1) The 100" telescope could ~~a~~ scan only one hemisphere of the sky — that visible from Mount Wilson.

(2) Actually, at any one time, it studied not more than 4 square degrees of the sky at any one time,- about one-ten-thousandth part of the sky [41,253 sq degrees] It would take years to complete its survey of half the sky.

(3) From the area studied, he had estimated that ~~the completed~~ when the survey was finished, the 100" might have found 75,000,000 galaxies. AND this might be only a small corner of the whole universe.-

(4) The velocity-distance relationship which he had found was ~~for~~ based on a study of 27 of these possible 75,000,000.

(5) When he spoke of velocity he meant the quantity c (the velocity of light) multiplied by the ratio of increase $\left(\frac{\Delta\lambda}{\lambda}\right)$ of the wave length.- This "red shift" was interpreted as recession on the assumption that 1000 million light-years away, the same laws of physics hold as do in our lab.-

One of those against whom Hubble was doing battle was Arthur [E.A] Milne, † 1950 Dublin. who had been a student (1919) of Eddington's and became Prof of Maths. at Oxford (1929) Milne was not an observing astronomer, and had no desire to be. He asserted that:

"the laws of nature can be derived by reason without recourse to experience" (Modern Cosmology and the Christian Idea of God, Oxford, 1952 (Posthumous)). — he would love ~~to see~~ astronomers discover that the ~~world~~ universe conformed to a pattern laid down for it by mathematics. —

~~His~~ His Kinematical Theory of Relativity received a poor reception from astronomers, but has contributed to the persistence in England of a school of Cosmologists who deem themselves free to expound theories for which there is no experimental foundation.

In Jan. 1939, uranium was split, for the 1st time, in Berlin. -

From then until the U.S. came into the war in Dec 1941, a good deal of the mathematical work done on nuclear ~~reaction~~ fission ~~was classified~~ ~~in the United States~~ fission was not hush-hush. -

In 1941 Dr Chan-ra-sek-har, of U. of Chicago worked out (and published in Astr Journ May 1942) the mathematics of what he called "Le Maitre's Egg" - he showed that Le Maitre's original matter, which started the universe could be a single clump of tightly-packed sub-atomic particles, with a density of 1000 million tons per cu. cm at a temp. of 8 000 million degrees. -

This would explain the relative amount of isotopes, the number of the elements we find, and the relations between protons & electrons. -

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Miss (Dr) Meitner at Berlin: U-238, got Barium, by bombarded with neutrons
On way to Stockholm got brain-wave, left next to Kryton with N=36

The first cosmologist to come forward with a new theory, after the war, was a German: Jordan of Stuttgart.

In his book. Die Herkunft der Sterne, Stuttgart, 1947, he suggested that the running down of the universe by arrested by the continuous creation of matter. —

1948 was notable for ~~two~~ ~~4~~ 5 contributions:

(1) a book by LeMaître, La Atome primitive, Genève, 1948.

It is practically a reiteration of the stand he took in 1931, with the addition of nuclear physics to show that his concept of a small dense mass with tremendous energy is in keeping with modern theories

R.A. Alpher The Origin of the chemical Elements (in collaboration with

(2) Geo Gamow of Geo W. U, published a paper in the Physical Review
and Bethe of Cornell.
74, 505 on the origin of the elements which was in essential accord with LeMaître's theory of the beginning of things
a highly compressed neutron gas with infinite density at zero point: rapid expansion with cooling
He swelled it into a book "The Creation of the Universe" 1952.
(N.Y. Viking Press).

(3) Bondi & Gold and their views on the steady-state theory in M. N. 108, 252.

(4) Fred Hoyle and his theory of the steady-state universe in M N. 108, 372

Gold at Greenwich 1955/

Meanwhile the observers were having an exciting time, indeed so much excitement, that they could afford to turn a deaf ear to the Cosmologists and go their way.-

Speaking generally, one can say that Mount Wilson and Mount Palomar are still engaged in endeavouring to check Einstein's theory.- ~~Spit shot Time~~ The majority are of opinion that it will be time enough to consider other opinions after he has been proved wrong.-

The most outstanding event in the past ten years has been the completion of the 200" telescope now in operation at Mount Palomar.-

Its work has been greatly aided by improved ~~cameras and spectrographs~~ spectrographs and other equipment which received many technical improvements during World War II.

Perhaps the most startling discovery of the 200" was that the nearest galaxy to us, the Spiral Galaxy in Andromeda, is twice as far away as was thought. - It is ~~nearly~~ more than a million and a half l-y away. -

A consequence of this is that the observed universe is now twice as big as was thought, because of the distance of the Galaxy in Andromeda had been used as the unit of measurement in recording the distances of the more distant ones. -

When the 200" was being designed, it was estimated that it could see a distance of 1000 million l-y. - Now it is believed it can see galaxies 2000 million l-y away. -

I said: we are hoping for more exciting discoveries this year:

The reason is that the 200" telescope in California is to be fitted with an image converter.

This is a device which the Californian astronomers saw in use at the Dublin observatory last September.

It is an electronic device - and boils down to using the 200" telescope as though it were an electronic television camera instead of an ordinary camera.

Indeed, to-day, it is practically nothing more than the telescopes lens for a camera.

In the new device, instead of inserting a photographic film at the focus of the telescope, they will install a photocathode. The light-image formed by the telescope when it falls on the photocathode will exchange its photons for electrons.

The rate of exchange is high. - For each photon one may get 10 electrons; it depends upon the Quantum efficiency of the cathode; and the multiplication constant determined by the cathodes; The electronic image is detected by receiving the electrons on a fluorescent screen. The new image may be 10 times brighter than the optical image. - First enthusiastic reports on what is to be done at Mt Palomar suggest that the 200" telescope, with image converter may be able to see as far as an optical 2000" telescope. - But I doubt it.