Evolution in the Expanding Universe

A LECTURE was delivered by the Abbé G. Lemaître, professor of mathematics in the University of Louvain, at Armstrong College, Newcastle-upon-Tyne, on the subject of "Evolution in the Expanding Universe" before a joint meeting of the Durham University Philosophical Society and the Newcastle Astronomical Society on February 12. Dr. R. A. Sampson, Astronomer Royal for Scotland, occupied the chair, and the speaker was welcomed by Sir William Marris.

The age of the universe, calculated from the observed recession of the nebulæ, is about $2 \cdot 4 \times 10^9$ years, whereas the ordinary theory of stellar evolution requires about 10^{13} years. If the matter in the universe were evenly distributed, the density would be 10^{-30} gm./cm.^{3}. The correction of Newton's law given by Einstein may be regarded as equivalent to a density, of negative sign, associated with space, and if accompanied with a positive pressure the system would be invariant in the Lorentz transformation. This density, a cosmical constant, works out at -10^{-27} gm./cm.^{3} and as this is greater than the average density of matter, the effect produced would be, in general, a repulsion.

Taking any point as centre, the motion for a nebula at distance r is represented by

$$\left(\frac{dr}{dt}\right)^2 = -h + \frac{2Gm}{r} + \frac{\lambda}{3} c^2 r^2.$$

The density of a vacuum is $\rho^v = \lambda c^2/4\pi G$, where G is the gravitational constant. Over large (spherical) areas this is to be regarded as a map in which distances normal to the radius vector are real, but those along it are in a scale $\sqrt{1 - h/c^2}$ where h is the energy constant in the equation of motion. (h varies as r^2, and m as r^3.) For some value $h = c^2$, the scale becomes zero and the map ends, but actually antipodal points are the same, like the points at the sides of a map on Mercator's projection.

Suppose now that the universe once consisted of matter with an average density greater than the critical, but with an initial velocity sufficient to carry it over the critical radius, this gives the proper expansion. When r is put equal to infinity in the above equation, only the last term is important, so that the velocity squared is equal to $\lambda/3\ c^2$, from which the cosmical constant may be obtained. Actually, there must have been fluctuating density in the initial state, and areas in which the separation of matter was less than the mean. In these, the matter would eventually fall back producing collapsing regions; more rarely, equilibrium areas would occur which would divide into collapsing regions. The first might produce nebulæ, the second, nebular clusters. If these areas coalesce, some loss of kinetic energy must take place due to encounters, and the original diffuse matter would agglomerate into stars.

A nebula has a mass of about 10^9 suns; its radius at critical density would be 10^5 light-years; the order of diameter is now about 1,000 light-years. The loss of kinetic energy will be

$$\frac{3}{2} G \frac{N^2 m^2}{R}$$

where N is the number of stars, m the average mass of each, R the radius. The gravitation energy of a star is

$$\frac{3}{2} G \frac{m^2}{r}$$

where r is the radius. Multiplying this by N gives the total, and dividing, $Nr/R = 6 \times 10^{-2} = 6$ per cent of the gravitation energy of the stars. This energy becomes heat, and the heat content of stars is of this order.

Regarding clusters, here also the right order is obtained. They should have the same densities, and this should be about the critical density. If N be the number of nebulæ in the cluster, m the mass of each,

$$Nm = c \times D^3 d^3$$

where D is diameter, and d angular diameter in degrees, and $c = 0 \cdot 155 V^2$ where V is the velocity of recession at 1 megaparsec. The observations of Hubble and Shapley give figures of the right order (10^9 suns).

Salmon and Trout Disease

IN the year 1911, cases of a hitherto unrecognised disease, causing death of large numbers of fish of various kinds, were reported from six rivers in the south-west of England. This was the first official record in Great Britain of the occurrence of furunculosis, a bacterial disease that has spread to many rivers in England and Wales and is now prevalent throughout Scotland. Serious outbreaks occurred in the Conway and Coquet districts in 1926 when salmon and migratory trout were attacked, and in the Kennet in 1924 and 1925, when the valuable brown-trout fisheries suffered, and in recent years the disease has continued to spread. While in 1932 there was a considerable abatement in the number of serious outbreaks in English rivers, in Scotland conditions were nearly as bad as ever.

The monetary loss entailed by the spread of this disease must be large, since in one river over a period of six years the estimated loss was £1,400, and in another larger river it was £2,000 in three years. But apart from this loss, there must be a more serious loss in the depletion of the breeding stock. The alarming increase in the number of outbreaks led to the setting up of a Furunculosis Committee in 1929, a copy of the second interim report of which is now before us.* The report indicates the satisfactory progress of research into the problem, carried out by a number of workers chiefly at the Bacteriological Laboratory of the University of Edinburgh, among whom Mrs. Isobel Blake deserves special mention.

Furunculosis is a disease caused by a bacillus, *B. salmonicida*, which infests salmon, trout and coarse fish; in advanced stages of the disease there may be lesions in the muscles, but in many cases death occurs without any obvious external symptoms and

* Second Interim Report of the Furunculosis Committee. (Edinburgh and London: H.M. Stationery Office, 1933.) 2*s*. 6*d*. net.