Georges Lemaître: An overview of his contributions to physics and cosmology

Vatican Observatory Conference, 2017
H. Kragh, Niels Bohr Institute, University of Copenhagen
Georges Édouard Lemaître

physicist and priest, pioneer of big-bang cosmology
Do the redshifts of the spiral nebulae vary systematically with their distances?

\[ z = \frac{\Delta \lambda}{\lambda} = kr \]
Utilisant les 42 nébuleuses figurant dans les listes de Hubble et de Strömgberg (1), et tenant compte de la vitesse propre du soleil (300 Km. dans la direction α = 315°, δ = 62°), on trouve une distance moyenne de 0,95 millions de parsecs et une vitesse radiale de 600 Km./sec, soit 625 Km./sec à 105 parsecs (2).

Nous adopterons donc
\[ R' = \frac{v}{rc} = \frac{625 \times 10^5}{10^4 \times 3,08 \times 10^{16} \times 3 \times 10^8} = 0,88 \times 10^{-27} \text{ cm}^{-1} \] (24)

Cette relation nous permet de calculer \( R_o \). Nous avons en effet par (16)
\[ \frac{R'}{R} = \frac{1}{R_o \sqrt{3} \sqrt{1 - 3y^2 + 2y^3}} \] (25)

où nous avons posé
\[ y = \frac{R_o}{R} \] (26)

D'autre part, d'après (18) et (26),
\[ R_o = \frac{y}{R} \] (27)

et donc
\[ 3 \left( \frac{R'}{R} \right)^2 R_o^2 = \frac{1}{3y^2 + 2y^3} \] (28)

Introduisant les valeurs numériques de \( \frac{R'}{R} \) (24) et de \( R_o \) (19), il vient :
\[ y = 0,0465 \]

On a alors :
\[ R = R_o \sqrt{y} = 0,215 R_o = 1,83 \times 10^{18} \text{ cm.} = 8 \times 10^9 \text{ parsecs} \]
\[ R_o = R y = R_o y^3 = 8,5 \times 10^{18} \text{ cm.} = 2,7 \times 10^9 \text{ parsecs} \]
\[ = 9 \times 10^9 \text{ années de lumière.} \]

(1) Il n'est pas tenu compte de N. G. C. 5194 qui est associé à N. G. C. 5195. L'introduction des nébulees de Magellan serait sans influence sur le résultat.
(2) En ne donnant pas de poids aux observations, on trouverait 670 Km./sec à 1,16 \times 10^5 parsecs, 575 Km./sec à 10^5 parsecs. Certains auteurs ont cherché à mettre en évidence la relation entre \( v \) et \( r \) et n'ont obtenu qu'une très faible corrélation entre ces deux grandeurs. L'erreur dans la détermination des distances individuelles est du même ordre de grandeur que l'intervalle que couvrent les observations et la vitesse propre des nébuleuses (en toute direction) est grande (300 Km./sec. d'après Strömgberg), il semble donc que ces résultats négatifs ne sont ni pour l'interprétation relativiste de l'effet Doppler. Tout ce que l'imprécision des observations permet de faire est de supposer \( v \) proportionnel à \( r \) et d'essayer d'éviter une erreur systématique dans la détermination du rapport \( v/r \). Cf. Lundsberg. The determination of the curvature of space time in de Sitter's world M. N., vol. 84, p. 747, 1929, et Strömgberg, l.c.
The incredible shrinking constant

Lemaître 1927 \[ H_0 \approx 625 \text{ km/s/Mpc} \]
Hubble 1931 \[ H_0 \approx 558 \text{ km/s/Mpc} \]
Planck 2015 \[ H_0 = 67.8 \text{ km/s/Mpc} \]
Lemaître-Eddington model (1927; 1930)

The universe (which has always existed) starts in an Einstein state and approaches a de Sitter state.
Lemaître’s “primeval atom” universe of 1931

Finite-space and finite-age model. Keeps cosmological constant ($\Lambda > 0$), which secures a “stagnation phase” and solves the time-scale difficulty.
The world started in a radioactive explosion of a "primordial atom" of density as an atomic nucleus.

The Beginning of the World from the Point of View of Quantum Theory.

SIR ARTHUR EDDINGTON states that, philosophically, the notion of a beginning of the present order of Nature is repugnant to him. I would rather be inclined to think that the present state of quantum theory suggests a beginning of the world very different from the present order of Nature. Thermodynamical

Clearly the initial quantum could not conceal in itself the whole course of evolution; but, according to the principle of indeterminacy, that is not necessary. Our world is now understood to be a world where something really happens; the whole story of the world need not have been written down in the first quantum like a song on the disc of a phonograph. The whole matter of the world must have been present at the beginning, but the story it has to tell may be written step by step.

G. LEMAITRE.

40 rue de Namur, Louvain.
Clearly the initial quantum could not conceive in itself the whole course of evolution; but, according to the indetermina-
tion principle, that is not necessary. Our world is now a world where something happens; the whole story of the world does not need to be written down in the first quantum as a song on the n

disc of a phonograph. The whole matter of the world must be present at the beginning, but the story it has to tell may be written step by step.

I think that every one who believes in a supreme being supporting every being and every acting, believes also that God is essentially hidden and may be glad to see how present physics provides a veil hiding the creation.


Big bang models without a big bang...
"According to Lemaître’s theory, all the matter in the universe was once packed within a single, gigantic atom, which ... burst, its fragments forming the stars of which our universe is built. ..."
The study of cosmic rays "gives some experimental support to the theory of super-radioactive origin of the cosmic radiation."

"The last two thousand million years are slow evolution ... ashes and smoke of bright but very rapid fireworks."
Computational cosmology?

In their calculations of energies and trajectories of charged particles in the Earth’s magnetic field, seen as a test of the primeval-atom hypothesis, Lemaître and Vallarta made use of MIT’s differential-analyzer computer developed by Vannevar Bush.
“I do not think that many cosmogonists have yet been persuaded by the theory of Lemaître. It is usually regarded as a brilliantly clever jeu d’esprit rather than a sober reconstruction of the beginning of the world.”


“Lemaître’s hypothesis is the wildest speculation of all ... an example of speculation run mad without a shred of evidence to support it.”

“We must be careful to keep our judgements uninfected by the demands of theology and unswerved by human hopes and fears.”

“The discovery of models, which start expansion from a singular state of zero volume, must not be confused with a proof that the actual universe was created at a finite time in the past.”

Tolman warns against “the evils of autistic and wishfulfilling thinking” in cosmology.
The problem of the universe is essentially an application of the law of gravitation to a region of extremely low density. The mean density of matter up to a distance of some ten millions of light years from us is of the order of $10^{-30}$ gr./cm.$^3$; if all the atoms of the stars were equally distributed through space there would be about one atom per cubic yard, or the total energy would be that of an equilibrium radiation at the temperature of liquid hydrogen. The theory of relativity points out the possibility of a modification of the law of gravitation under such extreme conditions. It suggests that, when we identify gravitational mass and energy, we have to introduce a constant. Everything happens as though the energy in vacuo would be different from zero. In order that absolute motion, i.e., motion relative to vacuum, may not be detected, we must associate a pressure $p = -\rho c^2$ to the density of energy $\rho c^2$ of vacuum. This is essentially the meaning of the cosmical constant $\lambda$ which corresponds to a negative density of vacuum $\rho_0$ according to

$$\rho_0 = \frac{\lambda c^2}{4\pi G} \approx 10^{-27} \text{ gr./cm.}^3$$

(1)
”The theory remains open to new developments which may connect the theoretically unknown value of the cosmical constant with other constants of physics.”

It is a "logical convenience" and was found by "a happy accident."

Lemaître to Einstein, 3 Oct 1947

”Since I have introduced this term I had always a bad conscience. ... I found it very ugly indeed ... and am unable to believe that such an ugly thing should be realized in nature.”

Einstein to Lemaître, 26 Sep 1947
SYMPOSIUM

on

THE PHYSICS OF THE UNIVERSE AND
THE NATURE OF PRIMORDIAL PARTICLES

TO BE HELD

AT THE UNIVERSITY OF NOTRE DAME

ON THE MONDAY AND TUESDAY OF MAY 2 AND 3, 1938.

PUBLIC LECTURES

1) Carl D. Anderson (California Institute of Technology) : The Basic
   Constituents of Matter.

2) Arthur H. Compton (University of Chicago) : Whence Cosmic Rays?

3) Harlow Shapley (Harvard University) : The Distribution of Matter in
   the Metagalaxy.

TECHNICAL PAPERS

4) Carl D. Anderson (California Institute of Technology) : Some Aspects
   of the Cosmic-ray Problem.

5) Gregory Breit (University of Wisconsin) : The Nature of the Forces
   between Primordial Particles.

6) J. F. Carlson (Purdue University) : The Theory of Cosmic-ray Particles.

7) Arthur H. Compton (University of Chicago) : Recent Research on Cosmic
   Rays.

8) Eugene Guth (University of Notre Dame) : The Relativistic Theory of
   Primordial Particles.

9) Arthur E. Haas (University of Notre Dame) : Cosmic Constants.

10) William D. Harkins (University of Chicago) : The Heat of the Stars and
    the Building of the Atoms in the Universe.

11) Canon Georges Lemaître (University of Louvain, Visiting Professor at
    the University of Notre Dame) : The Problem of the Expansion of
    the Universe.

12) Manuel S. Vallarta (Massachusetts Institute of Technology) : The Influence
    of the Magnetic Field of the Earth on Cosmic-ray Particles.
The conference, devoted to astrophysics and cosmology, had strong participation of steady-state theorists (Hoyle, Bondi, Gold, McCrea). Lemaître was alone in advocating models of the big-bang kind.
Lemaître and the Nobel Prize

As the first theoretical cosmologist ever, Lemaître was nominated for the Nobel Prize in physics, in 1954 for his prediction of the expanding universe.

But until the mid-1970s, the Nobel Committee did not admit astrophysics and cosmology as proper physics.

Remarkably, he was also nominated for the 1956 Nobel prize, this time for his primeval-atom theory, but in chemistry!