Ecuación de estado del universo

Mecánica Estadística 2016

Parte 1: Across the universe

et donc

$$\kappa\rho = \frac{\alpha}{R^3} + \frac{3\beta}{R^4} \tag{9}$$

Substituant dans (2), nous avons à intégrer

$$\frac{R'^2}{R^2} = \frac{\lambda}{3} - \frac{1}{R^2} + \frac{\kappa\rho}{3} = \frac{\lambda}{3} - \frac{1}{R^2} + \frac{\alpha}{3R^3} + \frac{\beta}{R^4} \tag{10}$$

ou

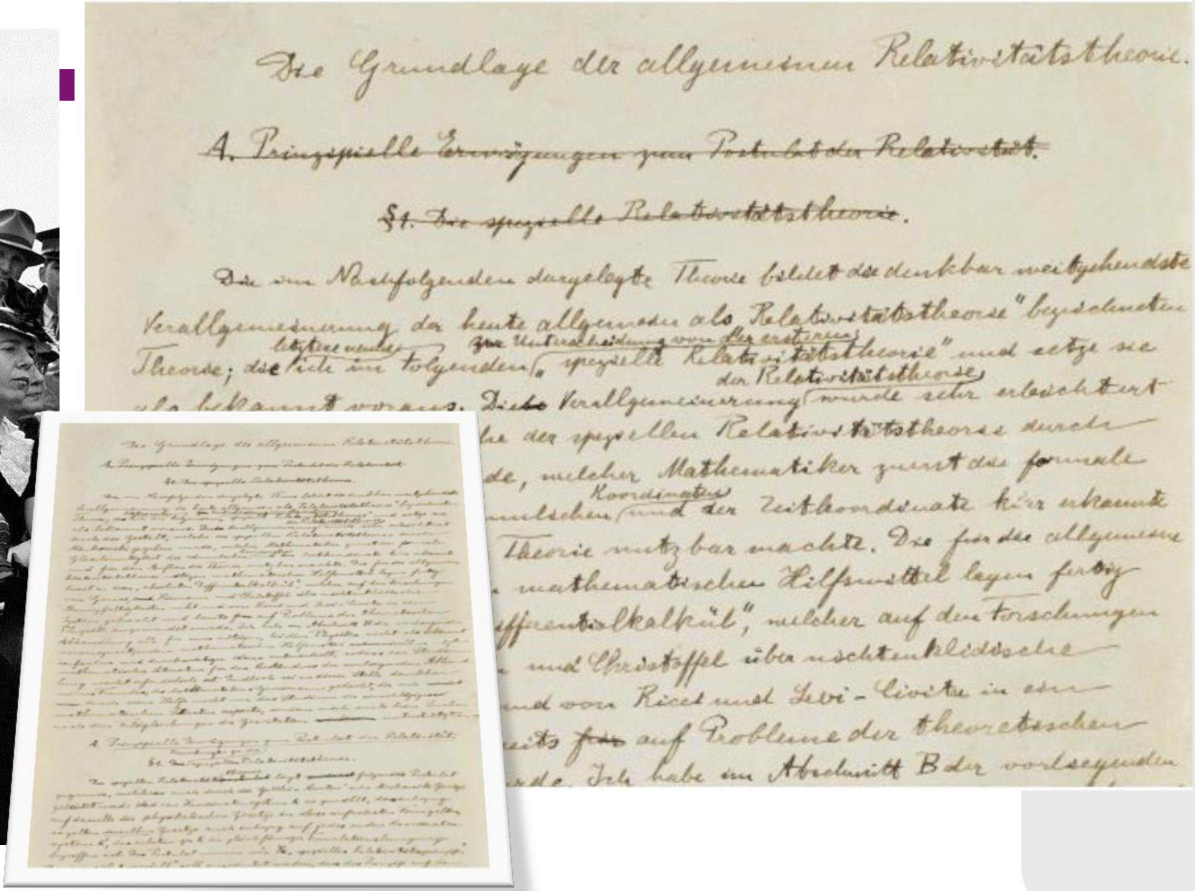
$$t = \int \frac{dR}{\sqrt{\frac{\lambda R^2}{3} - 1 + \frac{\alpha}{3R} + \frac{\beta}{R^2}}} \tag{11}$$

Pour α et β égaux à zéro, nous trouvons la solution de de Sitter (¹)

$$R = \sqrt{\frac{3}{\lambda}} \cosh \sqrt{\frac{\lambda}{3}} \, (t - t_0) \tag{12}$$

La solution d'Einstein s'obtient en posant $\beta = 0$ et R constant. Posant

1916-Einstein



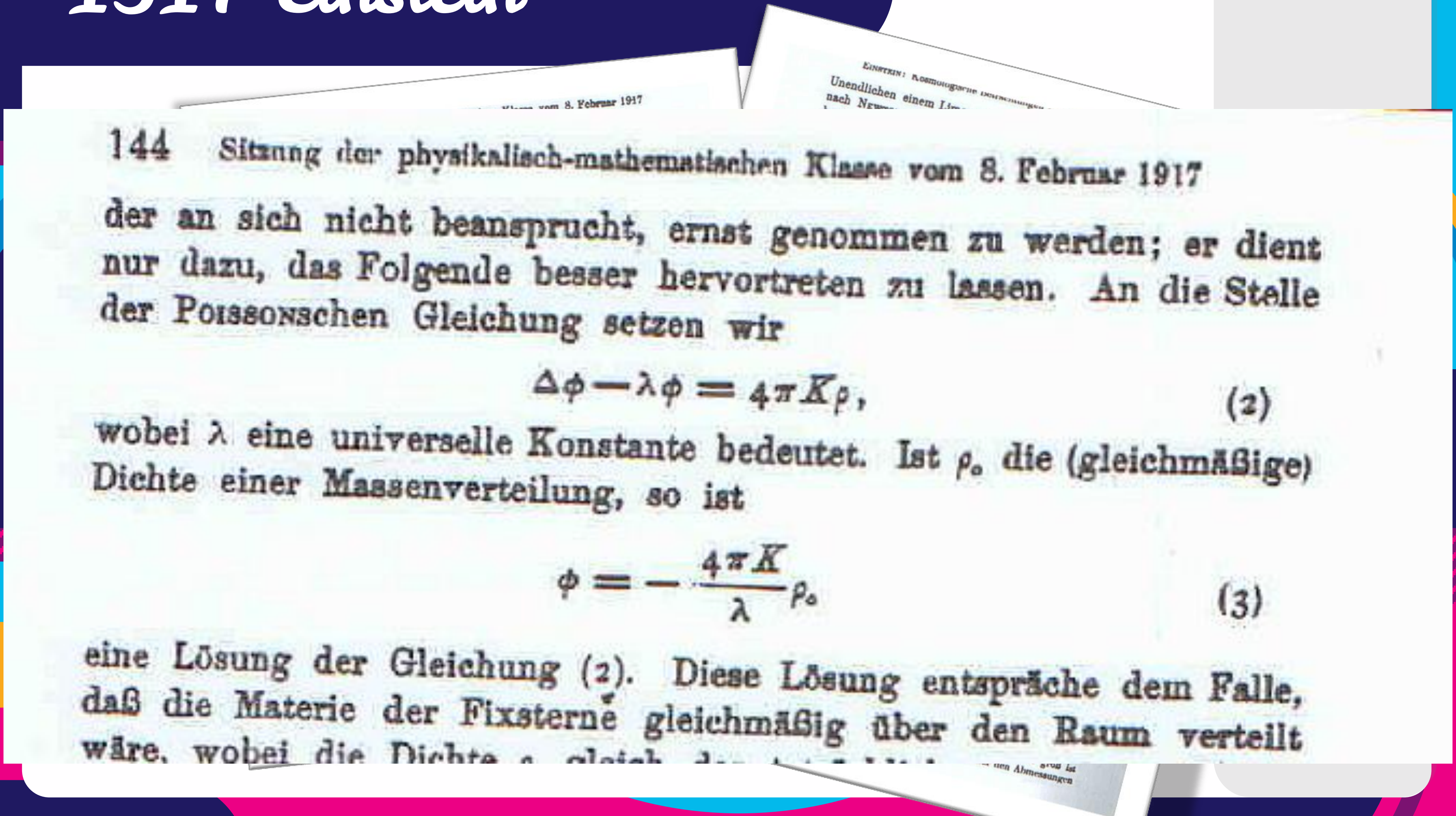
Die Grundlage der allgemeinen Relativitätstheorie.

~~A. Prinzipielle Erwägungen zum Postulat der Relativität.~~

~~§1. Die spezielle Relativitätstheorie.~~

Die im Nachfolgenden dargelegte Theorie bildet die denkbar weitgehendste
Verallgemeinerung der heute allgemein als „Relativitätstheorie" bezeichneten
Theorie; die letztere nenne ich im Folgenden „spezielle Relativitätstheorie" zur Unterscheidung von der ersteren und setze sie
als bekannt voraus. ~~Diese~~ Verallgemeinerung der Relativitätstheorie wurde sehr erleichtert
ke der speziellen Relativitätstheorie durch
de, welcher Mathematiker zuerst die formale
umlichen Koordinaten und der Zeitkoordinate klar erkannte
Theorie nutzbar machte. Die für die allgemeine
mathematischen Hilfsmittel lagen fertig
ifferentialkalkül", welcher auf den Forschungen
und Christoffel über nichteuklidische
und von Ricci und Levi-Civita in ein
eits ~~für~~ auf Probleme der theoretischen
ude. Ich habe im Abschnitt B der vorliegenden

1917-Einstein



144 Sitzung der physikalisch-mathematischen Klasse vom 8. Februar 1917

der an sich nicht beansprucht, ernst genommen zu werden; er dient nur dazu, das Folgende besser hervortreten zu lassen. An die Stelle der Poissonschen Gleichung setzen wir

$$\Delta\phi - \lambda\phi = 4\pi K\rho, \qquad (2)$$

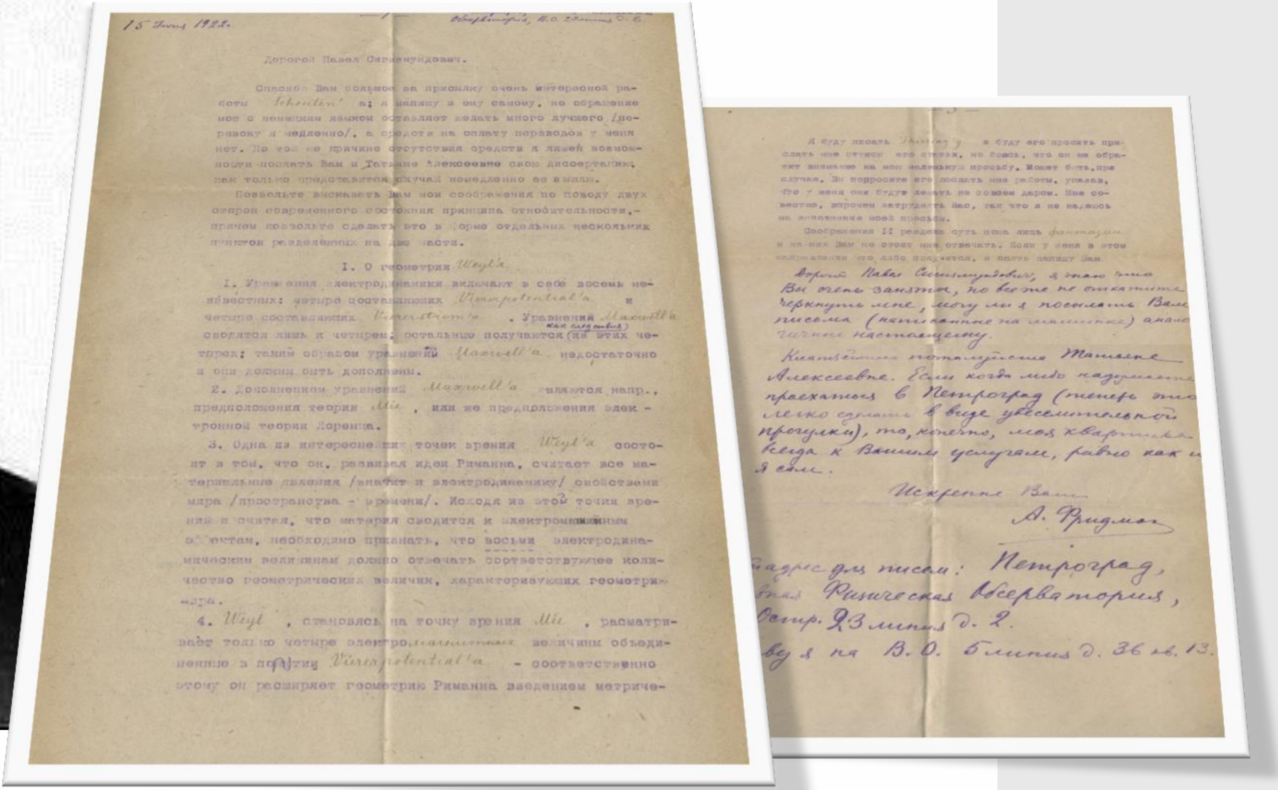
wobei λ eine universelle Konstante bedeutet. Ist ρ_0 die (gleichmäßige) Dichte einer Massenverteilung, so ist

$$\phi = -\frac{4\pi K}{\lambda}\rho_0 \qquad (3)$$

eine Lösung der Gleichung (2). Diese Lösung entspräche dem Falle, daß die Materie der Fixsterne gleichmäßig über den Raum verteilt wäre, wobei die Dichte

A Einstein. Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie. *Preussische Akademie der Wissenschaften, Sitzungsberichte*, **1917** 142–152

1922-A. Friedmann



15 Июня 1922 г.

— 1 —

Обсерватория, В.О. 2 линия д. 2.

Дорогой Павел Сигизмундович.

Спасибо Вам большое за присылку очень интересной работы Schouten'а; я напишу и ему самому, но обращение мое с немецким языком оставляет желать много лучшего /перевожу я медленно/, а средств на оплату переводов у меня нет. По той же причине отсутствия средств я лишен возможности послать Вам и Татьяне Алексеевне свою диссертацию; как только представится случай немедленно ее вышлю.

Позвольте высказать Вам мои соображения по поводу двух сторон современного состояния принципа относительности,- причем позвольте сделать это в форме отдельных нескольких пунктов разделенных на две части.

I. О геометрии Weyl'а

1. Уравнения электродинамики включают в себе восемь неизвестных: четыре составляющих Viererpotential'а и четыре составляющих Vierstrom'а. Уравнений Maxwell'а сводятся лишь к четырем; остальные получаются (как следствия) из этих четырех; таким образом уравнений Maxwell'а недостаточно и они должны быть дополнены.

2. Дополнением уравнений Maxwell'а являются напр., предположения теории Mie, или же предположения электронной теории Лоренца.

3. Одна из интереснейших точек зрения Weyl'а состоит в том, что он, развивая идеи Римана, считает все материальные явления /включая и электродинамику/ свойствами мира /пространства - времени/. Исходя из этой точки зрения и считая, что материя сводится к электромагнитным эффектам, необходимо признать, что восьми электродинамическим величинам должно отвечать соответствующее количество геометрических величин, характеризующих геометрию мира.

4. Weyl, становясь на точку зрения Mie, рассматривает только четыре электромагнитных величины объединенные в понятии Viererpotential'а - соответственно этому он расширяет геометрию Римана введением метриче-

— 3 —

Я буду писать [illegible]у и буду его просить прислать мне оттиск его статьи, но боюсь, что он не обратит внимание на мою маленькую просьбу. Может быть, при случае, Вы попросите его послать мне работы, указав, что у меня они будут лежать не совсем даром. Мне совестно, впрочем затруднять Вас, так что я не надеюсь на исполнение моей просьбы.

Соображения II раздела суть пока лишь фантазии и на них Вам не стоит мне отвечать. Если у меня в этом направлении что либо получится, я опять напишу Вам.

Дорогой Павел Сигизмундович, я знаю что Вы очень заняты, но все же не откажите черкнуть мне, могу ли я посылать Вам письма (написанные на машинке) аналогичные настоящему.

Кланяйтесь пожалуйста Татьяне Алексеевне. Если когда либо надумаете проехаться в Петроград (теперь это легко сделать в виде увеселительной прогулки), то, конечно, моя квартира всегда к Вашим услугам, равно как и я сам.

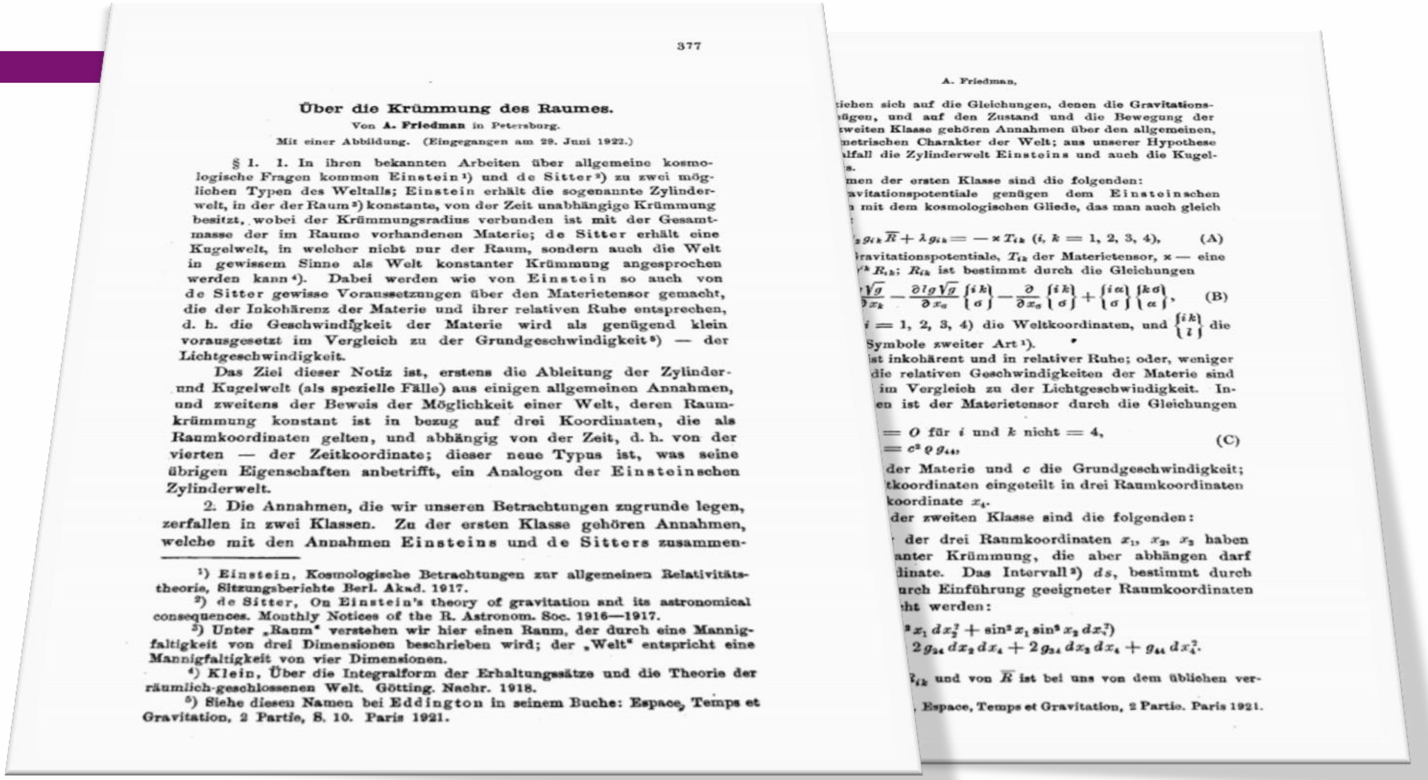
Искренне Ваш

А. Фридман

адрес для писем: Петроград,
ная Физическая Обсерватория,
Остр. 23 линия д. 2.
ву я на В.О. 6 линия д. 36 кв. 13.

Friedmann, Alexander (1922). «Über die Krümmung des Raumes». Zeitschrift für Physik A 10: 377-386

1924-A. Friedmann



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Über die Krümmung des Raumes.

Von **A. Friedman** in Petersburg.

Mit einer Abbildung. (Eingegangen am 29. Juni 1922.)

§ 1. 1. In ihren bekannten Arbeiten über allgemeine kosmologische Fragen kommen Einstein[1]) und de Sitter[2]) zu zwei möglichen Typen des Weltalls; Einstein erhält die sogenannte Zylinderwelt, in der der Raum[3]) konstante, von der Zeit unabhängige Krümmung besitzt, wobei der Krümmungsradius verbunden ist mit der Gesamtmasse der im Raume vorhandenen Materie; de Sitter erhält eine Kugelwelt, in welcher nicht nur der Raum, sondern auch die Welt in gewissem Sinne als Welt konstanter Krümmung angesprochen werden kann[4]). Dabei werden wie von Einstein so auch von de Sitter gewisse Voraussetzungen über den Materietensor gemacht, die der Inkohärenz der Materie und ihrer relativen Ruhe entsprechen, d. h. die Geschwindigkeit der Materie wird als genügend klein vorausgesetzt im Vergleich zu der Grundgeschwindigkeit[5]) — der Lichtgeschwindigkeit.

Das Ziel dieser Notiz ist, erstens die Ableitung der Zylinder- und Kugelwelt (als spezielle Fälle) aus einigen allgemeinen Annahmen, und zweitens der Beweis der Möglichkeit einer Welt, deren Raumkrümmung konstant ist in bezug auf drei Koordinaten, die als Raumkoordinaten gelten, und abhängig von der Zeit, d. h. von der vierten — der Zeitkoordinate; dieser neue Typus ist, was seine übrigen Eigenschaften anbetrifft, ein Analogon der Einsteinschen Zylinderwelt.

2. Die Annahmen, die wir unseren Betrachtungen zugrunde legen, zerfallen in zwei Klassen. Zu der ersten Klasse gehören Annahmen, welche mit den Annahmen Einsteins und de Sitters zusammen-

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[1]) Einstein, Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie, Sitzungsberichte Berl. Akad. 1917.

[2]) de Sitter, On Einstein's theory of gravitation and its astronomical consequences. Monthly Notices of the R. Astronom. Soc. 1916—1917.

[3]) Unter „Raum" verstehen wir hier einen Raum, der durch eine Mannigfaltigkeit von drei Dimensionen beschrieben wird; der „Welt" entspricht eine Mannigfaltigkeit von vier Dimensionen.

[4]) Klein, Über die Integralform der Erhaltungssätze und die Theorie der räumlich-geschlossenen Welt. Götting. Nachr. 1918.

[5]) Siehe diesen Namen bei Eddington in seinem Buche: Espace, Temps et Gravitation, 2 Partie, S. 10. Paris 1921.

A. Friedman,

iehen sich auf die Gleichungen, denen die Gravitations-
ügen, und auf den Zustand und die Bewegung der
weiten Klasse gehören Annahmen über den allgemeinen,
metrischen Charakter der Welt; aus unserer Hypothese
lfall die Zylinderwelt Einsteins und auch die Kugel-
s.
men der ersten Klasse sind die folgenden:
avitationspotentiale genügen dem Einsteinschen
mit dem kosmologischen Gliede, das man auch gleich

$g_{ik}\overline{R} + \lambda g_{ik} = -\varkappa T_{ik}$ $(i, k = 1, 2, 3, 4)$, (A)

ravitationspotentiale, T_{ik} der Materietensor, $\varkappa$ — eine
R_{ik}; R_{ik} ist bestimmt durch die Gleichungen

$\frac{\partial \lg \sqrt{g}}{\partial x_\sigma}\begin{Bmatrix} i\,k \\ \sigma \end{Bmatrix} - \frac{\partial}{\partial x_\sigma}\begin{Bmatrix} i\,k \\ \sigma \end{Bmatrix} + \begin{Bmatrix} i\,\alpha \\ \sigma \end{Bmatrix}\begin{Bmatrix} k\,\sigma \\ \alpha \end{Bmatrix}$, (B)

$= 1, 2, 3, 4)$ die Weltkoordinaten, und $\begin{Bmatrix} i\,k \\ l \end{Bmatrix}$ die
Symbole zweiter Art[1]).
ist inkohärent und in relativer Ruhe; oder, weniger
die relativen Geschwindigkeiten der Materie sind
im Vergleich zu der Lichtgeschwindigkeit. In-
en ist der Materietensor durch die Gleichungen

$= 0$ für i und k nicht $= 4$,
$= c^2 \varrho g_{44}$, (C)

der Materie und c die Grundgeschwindigkeit;
tkoordinaten eingeteilt in drei Raumkoordinaten
koordinate x_4.
der zweiten Klasse sind die folgenden:
der drei Raumkoordinaten x_1, x_2, x_3 haben
anter Krümmung, die aber abhängen darf
dinate. Das Intervall[2]) ds, bestimmt durch
urch Einführung geeigneter Raumkoordinaten
ht werden:

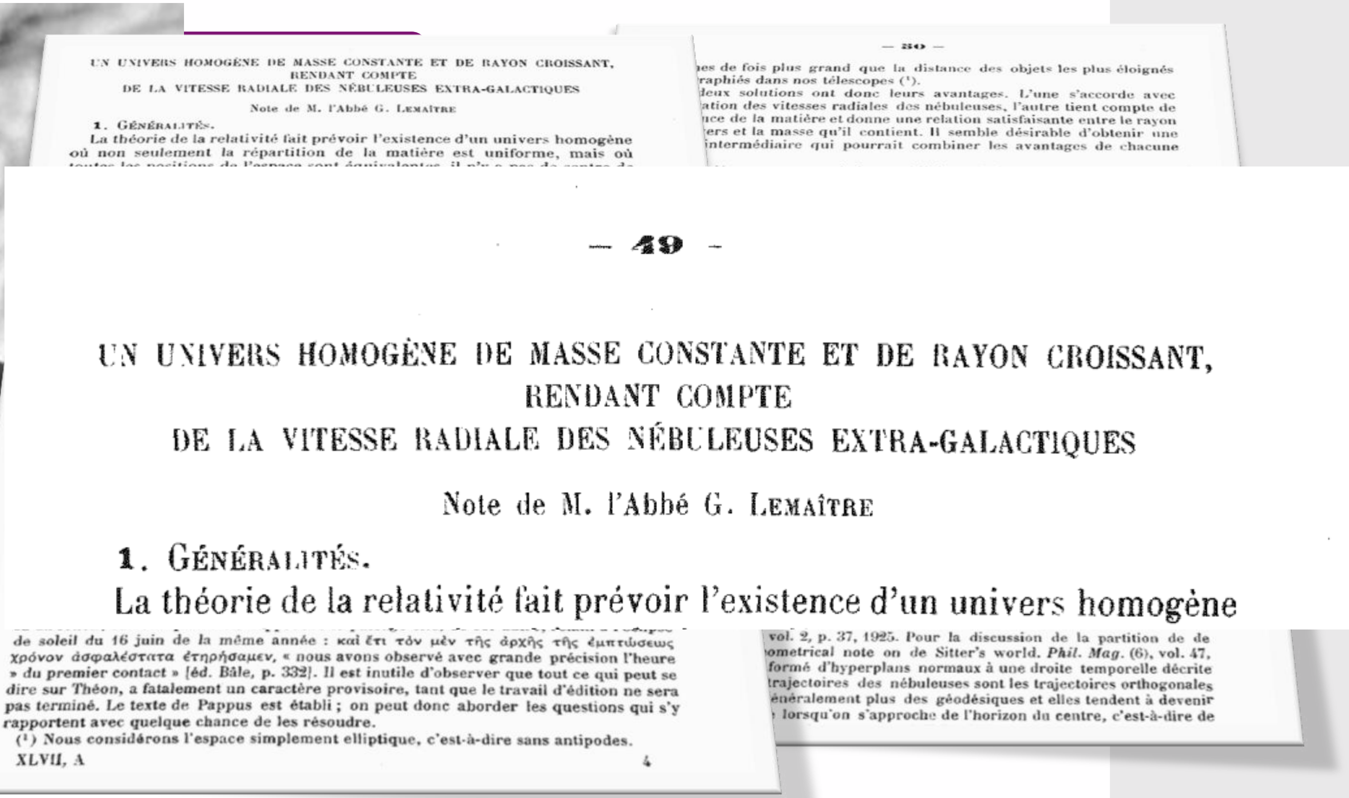
$x_1\, dx_2^2 + \sin^2 x_1 \sin^2 x_2\, dx_3^2)$
$2 g_{24}\, dx_2\, dx_4 + 2 g_{34}\, dx_3\, dx_4 + g_{44}\, dx_4^2$.

$_{ik}$ und von $\overline{R}$ ist bei uns von dem üblichen ver-

, Espace, Temps et Gravitation, 2 Partie. Paris 1921.

Friedmann, Alexander (1922). «Über die Krümmung des Raumes». Zeitschrift für Physik A 10: 377-386

1927-G. Lemaître



UN UNIVERS HOMOGÈNE DE MASSE CONSTANTE ET DE RAYON CROISSANT,
RENDANT COMPTE
DE LA VITESSE RADIALE DES NÉBULEUSES EXTRA-GALACTIQUES

Note de M. l'Abbé G. LEMAÎTRE

1. GÉNÉRALITÉS.

La théorie de la relativité fait prévoir l'existence d'un univers homogène où non seulement la répartition de la matière est uniforme, mais où

— 80 —

nes de fois plus grand que la distance des objets les plus éloignés
raphiés dans nos télescopes (¹).
deux solutions ont donc leurs avantages. L'une s'accorde avec
ation des vitesses radiales des nébuleuses, l'autre tient compte de
nce de la matière et donne une relation satisfaisante entre le rayon
ers et la masse qu'il contient. Il semble désirable d'obtenir une
intermédiaire qui pourrait combiner les avantages de chacune

— 49 —

UN UNIVERS HOMOGÈNE DE MASSE CONSTANTE ET DE RAYON CROISSANT,
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1. GÉNÉRALITÉS.

La théorie de la relativité fait prévoir l'existence d'un univers homogène

de soleil du 16 juin de la même année : καὶ ἔτι τὸν μὲν τῆς ἀρχῆς τῆς ἐμπτώσεως χρόνον ἀσφαλέστατα ἐτηρήσαμεν, « nous avons observé avec grande précision l'heure » du premier contact » [éd. Bâle, p. 332]. Il est inutile d'observer que tout ce qui peut se dire sur Théon, a fatalement un caractère provisoire, tant que le travail d'édition ne sera pas terminé. Le texte de Pappus est établi ; on peut donc aborder les questions qui s'y rapportent avec quelque chance de les résoudre.

(¹) Nous considérons l'espace simplement elliptique, c'est-à-dire sans antipodes.

XLVII, A 4

vol. 2, p. 37, 1925. Pour la discussion de la partition de de
ometrical note on de Sitter's world. *Phil. Mag.* (6), vol. 47,
formé d'hyperplans normaux à une droite temporelle décrite
trajectoires des nébuleuses sont les trajectoires orthogonales
énéralement plus des géodésiques et elles tendent à devenir
lorsqu'on s'approche de l'horizon du centre, c'est-à-dire de

G. Lemaitre. Un Univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extra-galactiques. Annales de la Société Scientifique de Bruxelles, A47, p. 49-59

Su física es espantosa

¨Sus cálculos son correctos
pero su física es espantosa¨

1929-E. Hubble

A RELATION BETWEEN DISTANCE AND RADIAL VELOCITY
AMONG EXTRA-GALACTIC NEBULAE

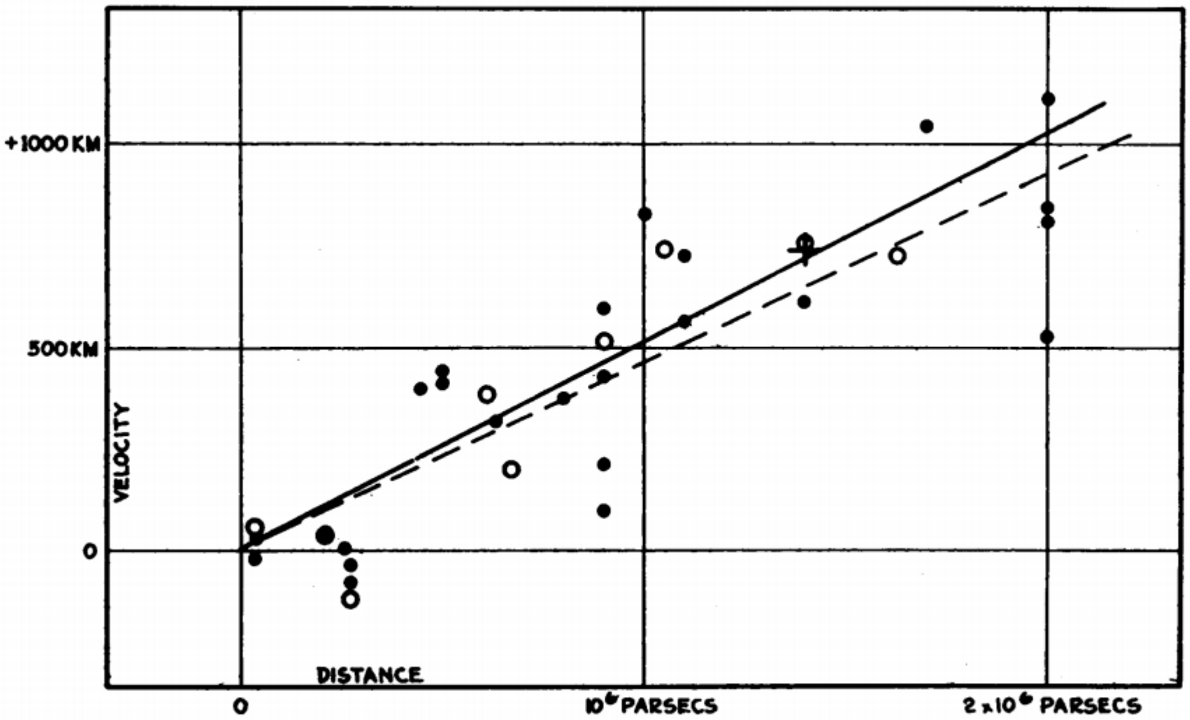
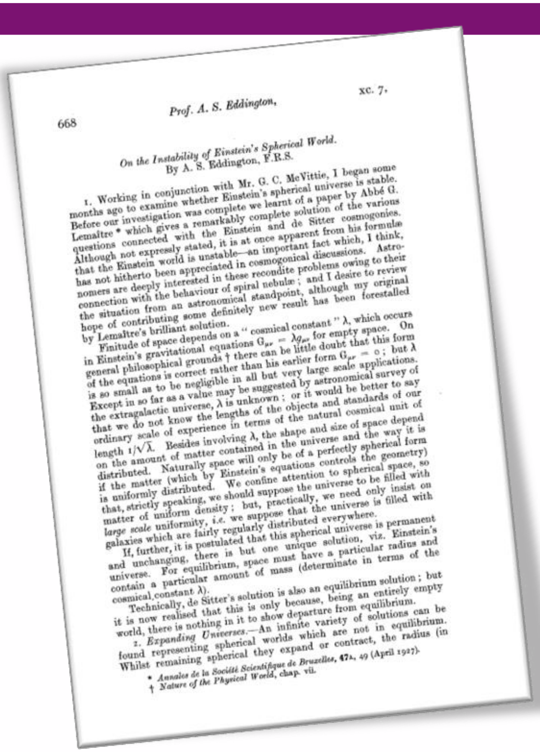


FIGURE 1

Hubble, E. P. A relation between distance and radial velocity among extra-galactic nebulae. Proc. Natl. Acad. Sci. USA, 15, 168 (1929)

A. S. Eddington



668 *Prof. A. S. Eddington,* xc. 7,

On the Instability of Einstein's Spherical World.
By A. S. Eddington, F.R.S.

1. Working in conjunction with Mr. G. C. McVittie, I began some months ago to examine whether Einstein's spherical universe is stable. Before our investigation was complete we learnt of a paper by Abbé G. Lemaître[*] which gives a remarkably complete solution of the various questions connected with the Einstein and de Sitter cosmogonies. Although not expressly stated, it is at once apparent from his formulæ that the Einstein world is unstable—an important fact which, I think, has not hitherto been appreciated in cosmogonical discussions. Astronomers are deeply interested in these recondite problems owing to their connection with the behaviour of spiral nebulæ; and I desire to review the situation from an astronomical standpoint, although my original hope of contributing some definitely new result has been forestalled by Lemaître's brilliant solution.

Finitude of space depends on a "cosmical constant" λ, which occurs in Einstein's gravitational equations $G_{\mu\nu} = \lambda g_{\mu\nu}$ for empty space. On general philosophical grounds[†] there can be little doubt that this form of the equations is correct rather than his earlier form $G_{\mu\nu} = 0$; but λ is so small as to be negligible in all but very large scale applications. Except in so far as a value may be suggested by astronomical survey of the extragalactic universe, λ is unknown; or it would be better to say that we do not know the lengths of the objects and standards of our ordinary scale of experience in terms of the natural cosmical unit of length $1/\sqrt{\lambda}$. Besides involving λ, the shape and size of space depend on the amount of matter contained in the universe and the way it is distributed. Naturally space will only be of a perfectly spherical form if the matter (which by Einstein's equations controls the geometry) is uniformly distributed. We confine attention to spherical space, so that, strictly speaking, we should suppose the universe to be filled with matter of uniform density; but, practically, we need only insist on *large scale* uniformity, *i.e.* we suppose that the universe is filled with galaxies which are fairly regularly distributed everywhere.

If, further, it is postulated that this spherical universe is permanent and unchanging, there is but one unique solution, viz. Einstein's universe. For equilibrium, space must have a particular radius and contain a particular amount of mass (determinate in terms of the cosmical constant λ).

Technically, de Sitter's solution is also an equilibrium solution; but it is now realised that this is only because, being an entirely empty world, there is nothing in it to show departure from equilibrium.

2. *Expanding Universes.*—An infinite variety of solutions can be found representing spherical worlds which are not in equilibrium. Whilst remaining spherical they expand or contract, the radius (in

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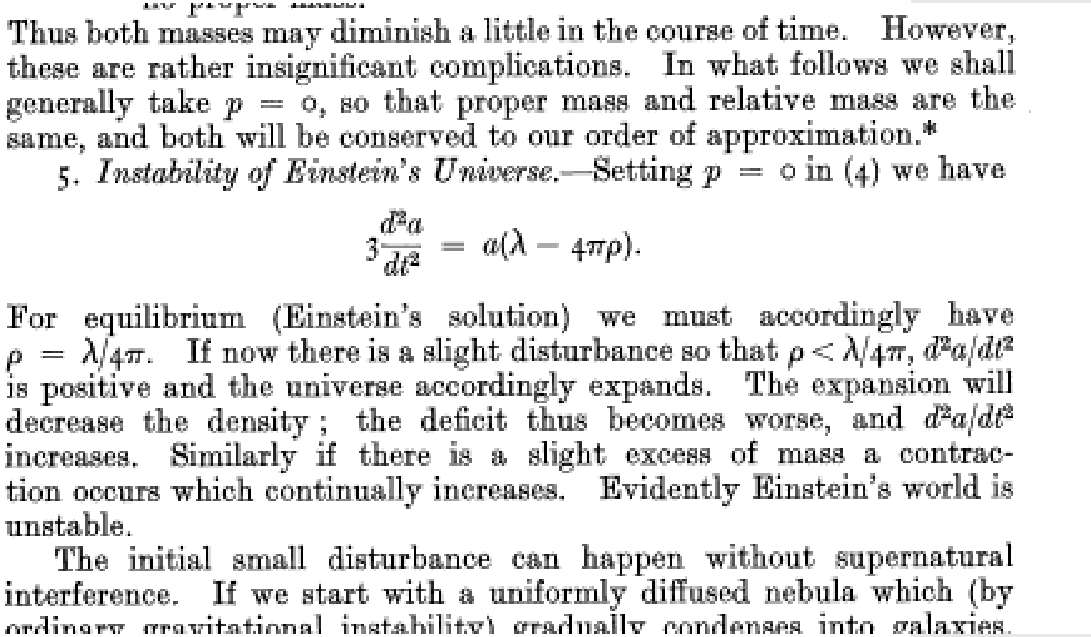
[*] *Annales de la Société Scientifique de Bruxelles*, **47A**, 49 (April 1927).

[†] *Nature of the Physical World*, chap. vii.



Thus both masses may diminish a little in the course of time. However, these are rather insignificant complications. In what follows we shall generally take $p = 0$, so that proper mass and relative mass are the same, and both will be conserved to our order of approximation.*

5. *Instability of Einstein's Universe.*—Setting $p = 0$ in (4) we have

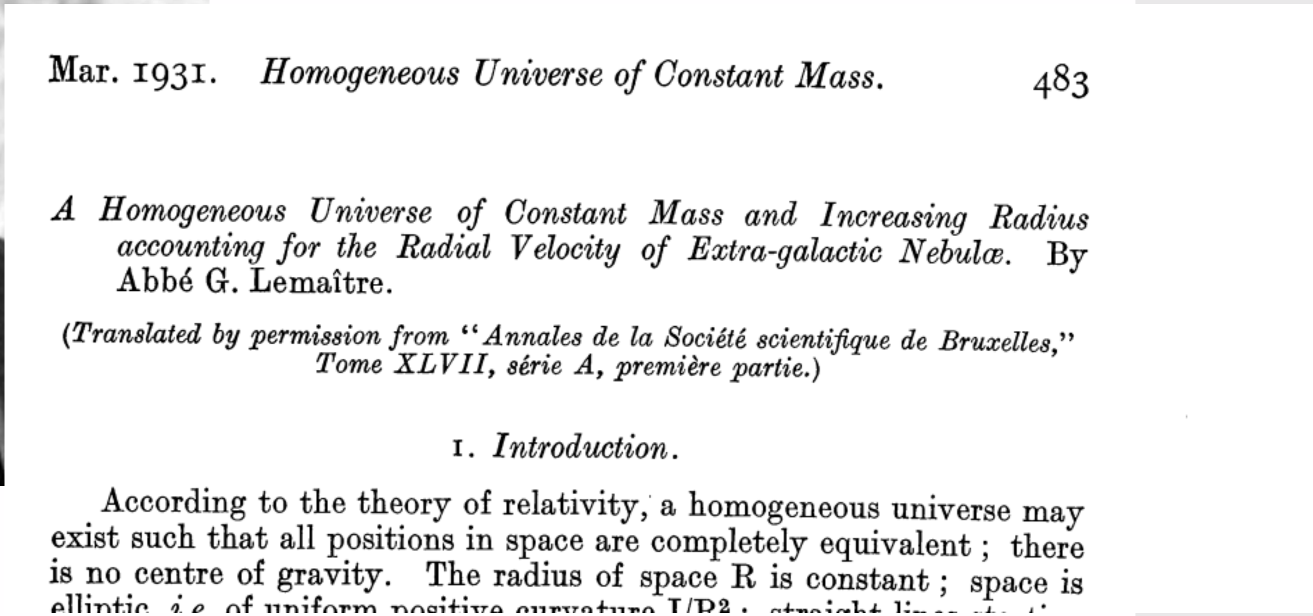
$$3\frac{d^2a}{dt^2} = a(\lambda - 4\pi\rho).$$

For equilibrium (Einstein's solution) we must accordingly have $\rho = \lambda/4\pi$. If now there is a slight disturbance so that $\rho < \lambda/4\pi$, d^2a/dt^2 is positive and the universe accordingly expands. The expansion will decrease the density; the deficit thus becomes worse, and d^2a/dt^2 increases. Similarly if there is a slight excess of mass a contraction occurs which continually increases. Evidently Einstein's world is unstable.

The initial small disturbance can happen without supernatural interference. If we start with a uniformly diffused nebula which (by ordinary gravitational instability) gradually condenses into galaxies,

Eddington, A. S. (1930). On the instability of Einstein's spherical world. Monthly Notices of the Royal Astronomical Society, 90, 668-678.

1931-G. Lemaître



A Homogeneous Universe of Constant Mass and Increasing Radius accounting for the Radial Velocity of Extra-galactic Nebulæ. By Abbé G. Lemaître.

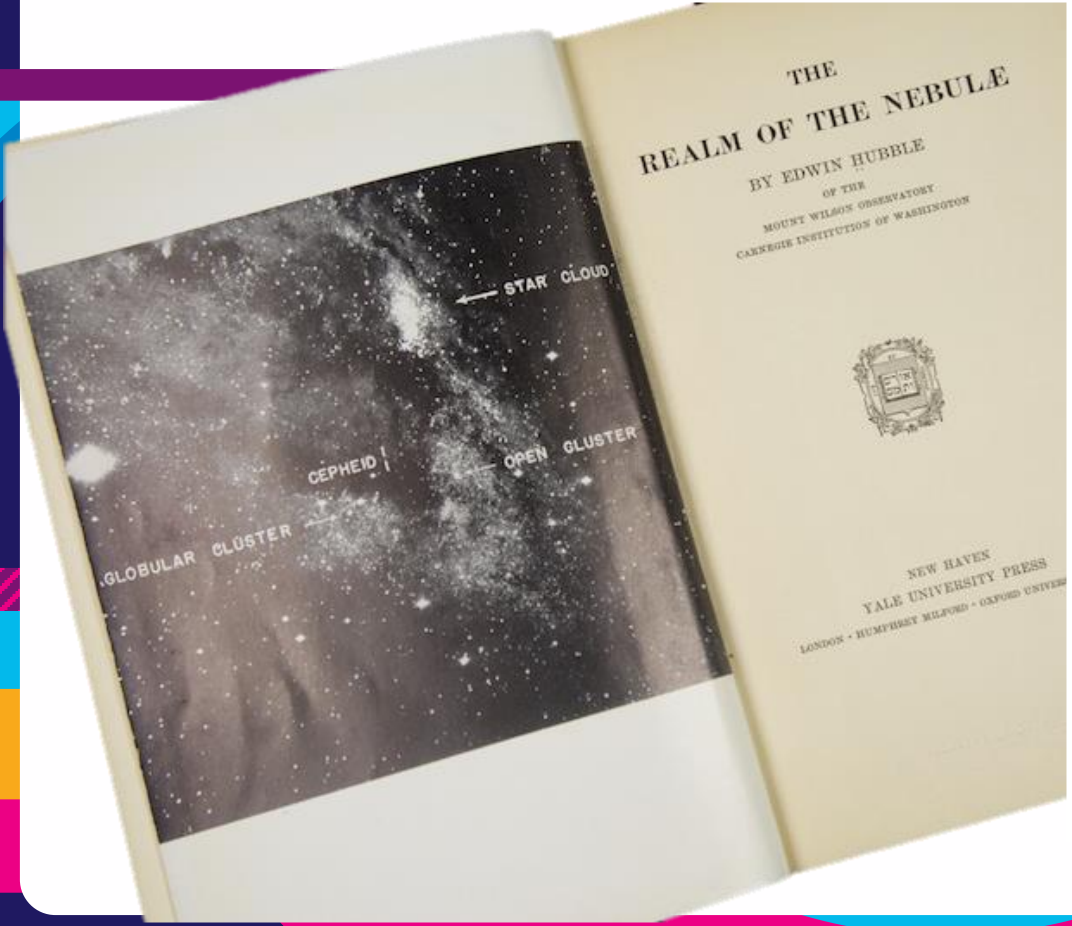
(*Translated by permission from "Annales de la Société scientifique de Bruxelles," Tome XLVII, série A, première partie.*)

1. *Introduction.*

According to the theory of relativity, a homogeneous universe may exist such that all positions in space are completely equivalent; there is no centre of gravity. The radius of space R is constant; space is elliptic, *i.e.* of uniform positive curvature $1/R^2$; straight lines

Lemaitre, A. G. (1931). A homogeneous universe of constant mass and increasing radius accounting for the radial velocity of extra-galactic nebulae. Monthly Notices of the Royal Astronomical Society, 91(5), 483-490.

Hubble vs. Lemaître



THE
REALM OF THE NEBULÆ
BY EDWIN HUBBLE
OF THE
MOUNT WILSON OBSERVATORY
CARNEGIE INSTITUTION OF WASHINGTON

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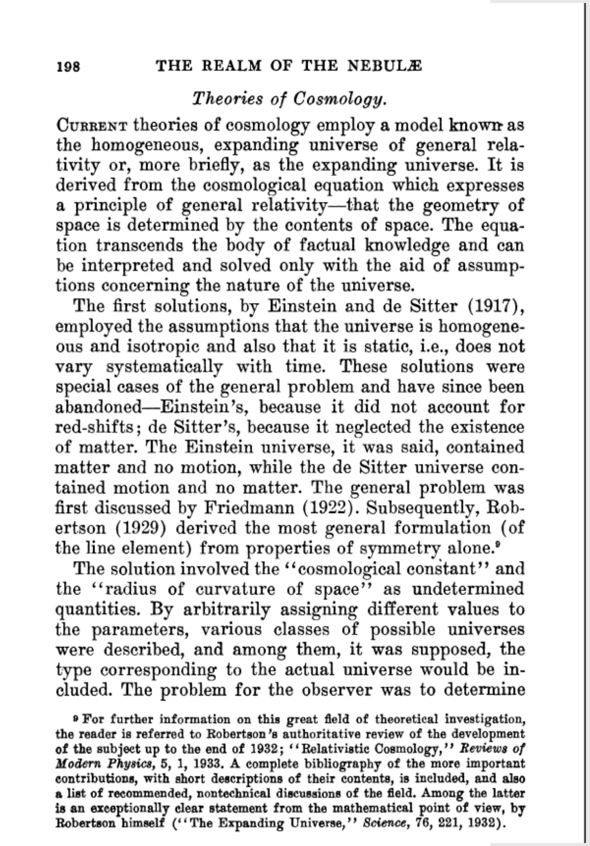


198 THE REALM OF THE NEBULÆ

Theories of Cosmology.

Current theories of cosmology employ a model known as the homogeneous, expanding universe of general relativity or, more briefly, as the expanding universe. It is derived from the cosmological equation which expresses a principle of general relativity—that the geometry of space is determined by the contents of space. The equation transcends the body of factual knowledge and can be interpreted and solved only with the aid of assumptions concerning the nature of the universe.

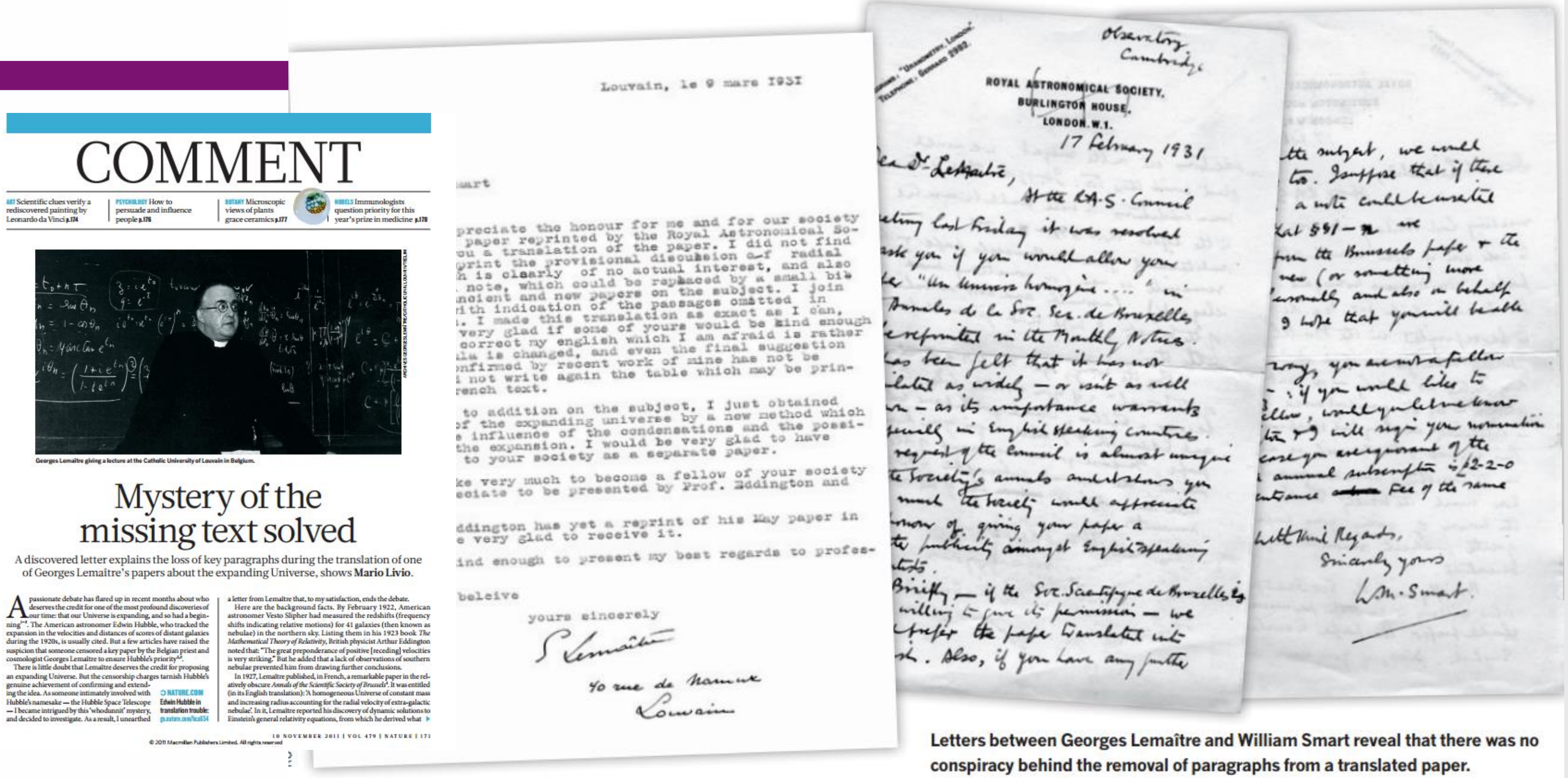
The first solutions, by Einstein and de Sitter (1917), employed the assumptions that the universe is homogeneous and isotropic and also that it is static, i.e., does not vary systematically with time. These solutions were special cases of the general problem and have since been abandoned—Einstein's, because it did not account for red-shifts; de Sitter's, because it neglected the existence of matter. The Einstein universe, it was said, contained matter and no motion, while the de Sitter universe contained motion and no matter. The general problem was first discussed by Friedmann (1922). Subsequently, Robertson (1929) derived the most general formulation (of the line element) from properties of symmetry alone.[9]

The solution involved the "cosmological constant" and the "radius of curvature of space" as undetermined quantities. By arbitrarily assigning different values to the parameters, various classes of possible universes were described, and among them, it was supposed, the type corresponding to the actual universe would be included. The problem for the observer was to determine

[9] For further information on this great field of theoretical investigation, the reader is referred to Robertson's authoritative review of the development of the subject up to the end of 1932; "Relativistic Cosmology," *Reviews of Modern Physics*, 5, 1, 1933. A complete bibliography of the more important contributions, with short descriptions of their contents, is included, and also a list of recommended, nontechnical discussions of the field. Among the latter is an exceptionally clear statement from the mathematical point of view, by Robertson himself ("The Expanding Universe," *Science*, 76, 221, 1932).

E. Hubble. The realm of the nebule. 1936

Hubble vs. Lemaître



COMMENT

ART Scientific clues verify a rediscovered painting by Leonardo da Vinci p.174

PSYCHOLOGY How to persuade and influence people p.176

BOTANY Microscopic views of plants grace ceramics p.177

NOBELS Immunologists question priority for this year's prize in medicine p.178

Georges Lemaître giving a lecture at the Catholic University of Louvain in Belgium.

Mystery of the missing text solved

A discovered letter explains the loss of key paragraphs during the translation of one of Georges Lemaître's papers about the expanding Universe, shows **Mario Livio**.

A passionate debate has flared up in recent months about who deserves the credit for one of the most profound discoveries of our time: that our Universe is expanding, and so had a beginning[1–3]. The American astronomer Edwin Hubble, who tracked the expansion in the velocities and distances of scores of distant galaxies during the 1920s, is usually cited. But a few articles have raised the suspicion that someone censored a key paper by the Belgian priest and cosmologist Georges Lemaître to ensure Hubble's priority[2,3].

There is little doubt that Lemaître deserves the credit for proposing an expanding Universe. But the censorship charges tarnish Hubble's genuine achievement of confirming and extending the idea. As someone intimately involved with Hubble's namesake — the Hubble Space Telescope — I became intrigued by this 'whodunnit' mystery, and decided to investigate. As a result, I unearthed a letter from Lemaître that, to my satisfaction, ends the debate.

Here are the background facts. By February 1922, American astronomer Vesto Slipher had measured the redshifts (frequency shifts indicating relative motions) for 41 galaxies (then known as nebulae) in the northern sky. Listing them in his 1923 book *The Mathematical Theory of Relativity*, British physicist Arthur Eddington noted that: "The great preponderance of positive [receding] velocities is very striking." But he added that a lack of observations of southern nebulae prevented him from drawing further conclusions.

In 1927, Lemaître published, in French, a remarkable paper in the relatively obscure *Annals of the Scientific Society of Brussels*[4]. It was entitled (in its English translation): 'A homogeneous Universe of constant mass and increasing radius accounting for the radial velocity of extra-galactic nebulae'. In it, Lemaître reported his discovery of dynamic solutions to Einstein's general relativity equations, from which he derived what ▸

NATURE.COM
Edwin Hubble in translation trouble:
go.nature.com/lca854

Louvain, le 9 mars I93I

mart

preciate the honour for me and for our society
paper reprinted by the Royal Astronomical So-
ou a translation of the paper. I did not find
print the provisional discussion of radial
h is clearly of no actual interest, and also
note, which could be replaced by a small bib
ncient and new papers on the subject. I join
ith indication of the passages omitted in
. I made this translation as exact as I can,
very glad if some of yours would be kind enough
correct my english which I am afraid is rather
la is changed, and even the final suggestion
nfirmed by recent work of mine has not be
not write again the table which may be prin-
rench text.

to addition on the subject, I just obtained
f the expanding universe by a new method which
e influence of the condensations and the possi-
the expansion. I would be very glad to have
to your society as a separate paper.

ke very much to become a fellow of your society
eciate to be presented by Prof. Eddington and

ddington has yet a reprint of his May paper in
e very glad to receive it.

ind enough to present my best regards to profes-

beleive

yours sincerely

G Lemaître

40 rue de Namur
Louvain

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ams: "Uranometry, London."
Telephone: Gerrard 2982.

ROYAL ASTRONOMICAL SOCIETY,
BURLINGTON HOUSE,
LONDON. W.1.

Observatory
Cambridge

17 February 1931

ear Dr Lemaître,

At the R.A.S. Council
eting last Friday it was resolved
ask you if you would allow your
le "Un Univers homogène ...." in
Annales de la Soc. Sci. de Bruxelles
e reprinted in the Monthly Notices.
has been felt that it has not
lated as widely — or isn't as well
n — as its importance warrants
pecially in English speaking countries.
request of the Council is almost unique
the Society's annals and it shows you
much the Society would appreciate
honour of giving your paper a
publicity amongst English speaking
tists.
Briefly — if the Soc. Scientifique de Bruxelles is
willing to give its permission — we
prefer the paper translated into
sh. Also, if you have any further

the subject, we would
to. I suppose that if there
a note could be inserted
that §§1–n are
from the Brussels paper & the
new (or something more
Personally and also on behalf
I hope that you will be able

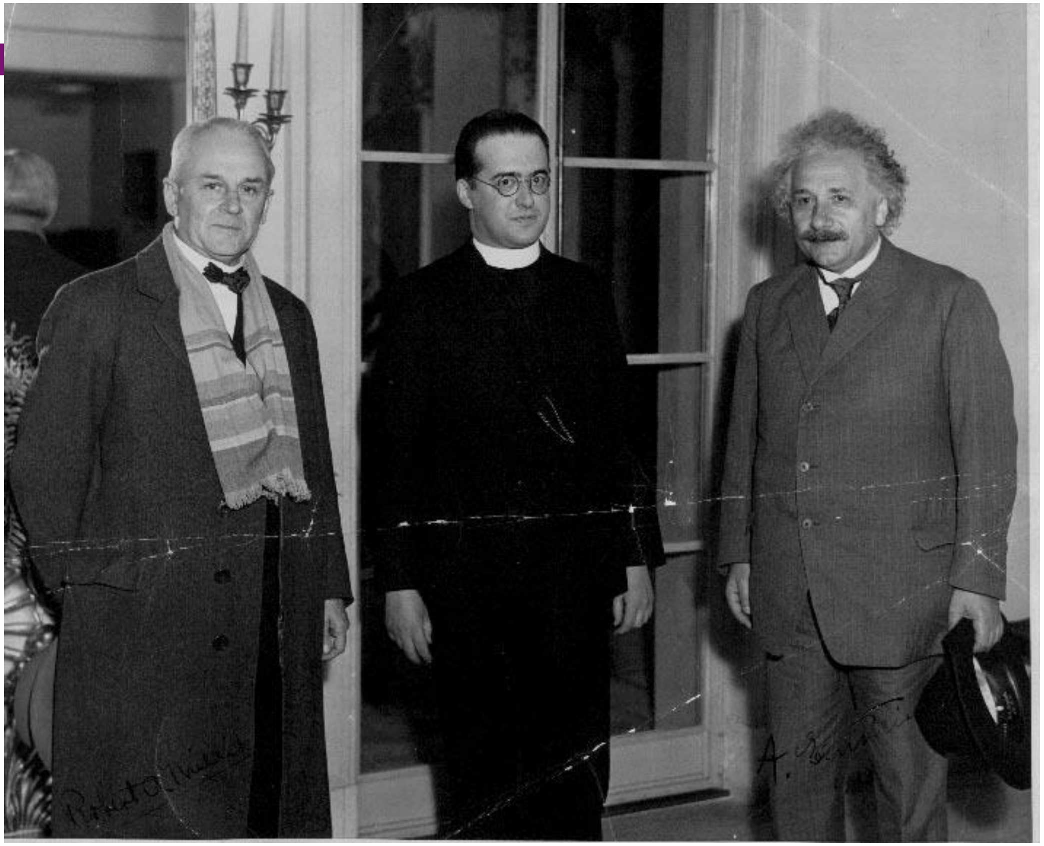
way, you are not a fellow
– ; if you would like to
Fellow, would you let me know
the R.S. will sign your nomination
case you are ignorant of the
annual subscription is £2-2-0
entrance fee of the same

With kind Regards,
Sincerely yours
W. M. Smart.

Letters between Georges Lemaître and William Smart reveal that there was no conspiracy behind the removal of paragraphs from a translated paper.

Livio, M. (2011). Lost in translation: Mystery of the missing text solved. Nature,479(7372), 171-173.

1933-Pasadena



¨Esta es la explicación más hermosa y satisfactoria de la creación que haya escuchado jamás¨

1933-Pasadena

THE NEW YORK TIMES MAGAZINE, FEBRUARY 19, 1933. 3

LEMAITRE FOLLOWS TWO PATHS TO TRUTH

The Famous Physicist, Who Is Also a Priest, Tells Why He Finds No Conflict Between Science and Religion

By DUNCAN AIKMAN

PASADENA.

"THERE is no conflict between religion and science," the Abbé Lemaitre has been telling audiences over and over again in this country and then proving it by explaining the aims of both. His view is interesting and important not because he is a Catholic priest, not because he is one of the leading mathematical physicists of our time, but because he is both. Here is a man who believes firmly in the Bible as a revelation from on high, but who develops a theory of the universe without the slightest regard for the teachings of revealed religion on genesis. And there is no conflict!

Such an attitude would have been preposterous to a Victorian physicist. Either you accept the whole Book of Genesis and therefore shut yourself out of the world of science, or you accept science and repudiate the prophets as expositors of the manner in which the universe began. Today the physicist is meeker. Behind his formulas there is something that is still veiled. He is half mystic and ready to admit that the universe may reveal itself in other ways than in mathematical equations or the bands and lines of a spectograph. The abbé, therefore, follows the trend of modern thinking and derives from it more than ordinary satisfaction because he happens to be trained in theology as well as in mathematical physics.

Lemaitre, like Eddington, finds that science and religion supplement each other. Science can never study the universe as a whole. It selects a small portion, as much as it can handle, and then makes deductions. To a cosmologist the earth and Mars are only planets wheeling around the sun. Are they inhabited? Are they washed by air and water? Why were they created? Is there purpose in the universe? Science is indifferent to such questions, but not religion.

that there must be authentic religious dogma in the binomial theorem. Nevertheless a lot of otherwise intelligent and well-educated men do go on believing or at least acting on such a belief. When they find the Bible's scientific references wrong, as they often are, they repudiate it utterly. Should a priest reject relativity because it

that it took perhaps ten thousand million years to create what we think is the universe. Genesis is simply trying to teach us that one day in seven should be devoted to rest, worship and reverence—all necessary to salvation."

"And that story about Jonah and the big fish?

"I admit that a whale cannot

powers with which they are credited in the Bible.

"If scientific knowledge were necessary to salvation," he says, "it would have been revealed to the writers of the Scriptures and they would have set it down in their verses. For instance, the doctrine of the Trinity is much more abstruse than anything in relativity or

question of salvation. On other questions they were as wise or as ignorant as their generation. Hence it is utterly unimportant that errors of historic and scientific fact should be found in the Bible, especially if errors relate to events that were not directly observed by those who wrote about them. The idea that because they were right in their doctrine of immortality and salvation they must also be right on all other subjects is simply the fallacy of people who have an incomplete understanding of why the Bible was given to us at all."

Lemaitre tells of a classroom scene in which he figured. An old father was expounding at the desk. Before him sat the lad who was to discover the expanding universe and who, even then, was brimful of science. In his eagerness the lad read into a passage of Genesis an anticipation of modern science.

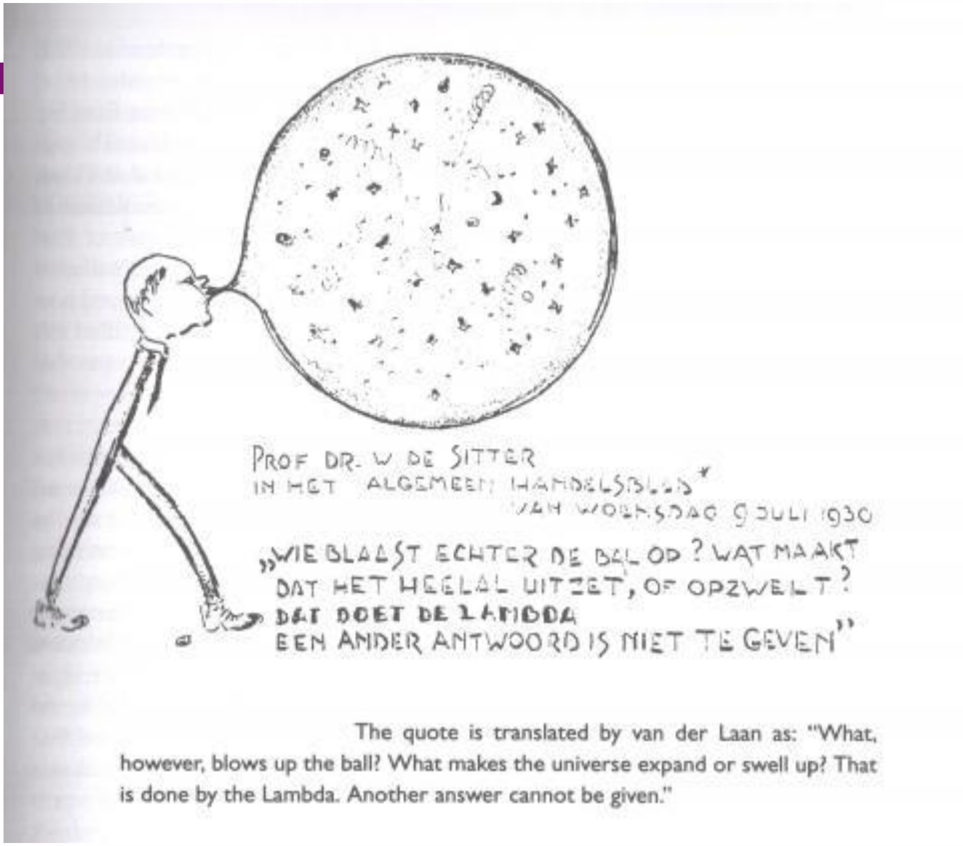
"I pointed it out," says Lemaitre, "but the old Father was skeptical. 'If there is a coincidence,' he decided, 'it is of no importance. Also if you should prove to me that it exists I would consider it unfortunate. It will merely encourage more thoughtless people to imagine that the Bible teaches infallible science, whereas the most we can say is that occasionally one of the prophets made a correct scientific guess.'"

* * *

THERE is, the abbé admits, a varying sense of conflict between science and religion in the different branches of science. "The biologists seem to have peculiar difficulties," he reasons. "There is every reason for this. They have only recently discovered a few guiding laws and principles. Hence, in the past their studies have been confusing rather than enlightening. In a way their subject-matter has been gross.

"But give the biologist more laws like those of the Abbé Mendel and a new spirit is bound to awaken. The sense that this is a morally

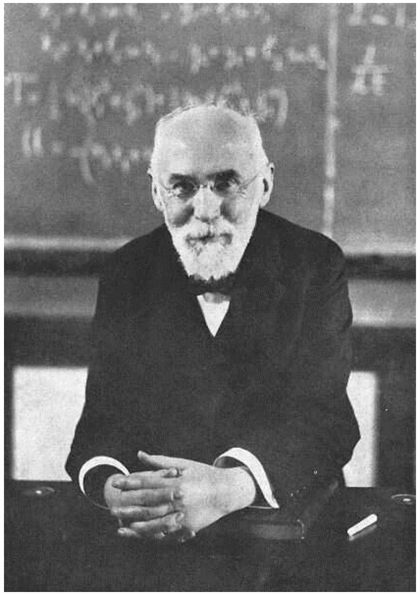
de-Sitter



PROF DR. W DE SITTER
IN HET ALGEMEEN HANDELSBLAD*
VAN WOENSDAG 9 JULI 1930

„WIE BLAAST ECHTER DE BAL OP? WAT MAAKT
DAT HET HEELAL UITZET, OF OPZWELT?
DAT DOET DE LAMBDA
EEN ANDER ANTWOORD IS NIET TE GEVEN"

The quote is translated by van der Laan as: "What, however, blows up the ball? What makes the universe expand or swell up? That is done by the Lambda. Another answer cannot be given."



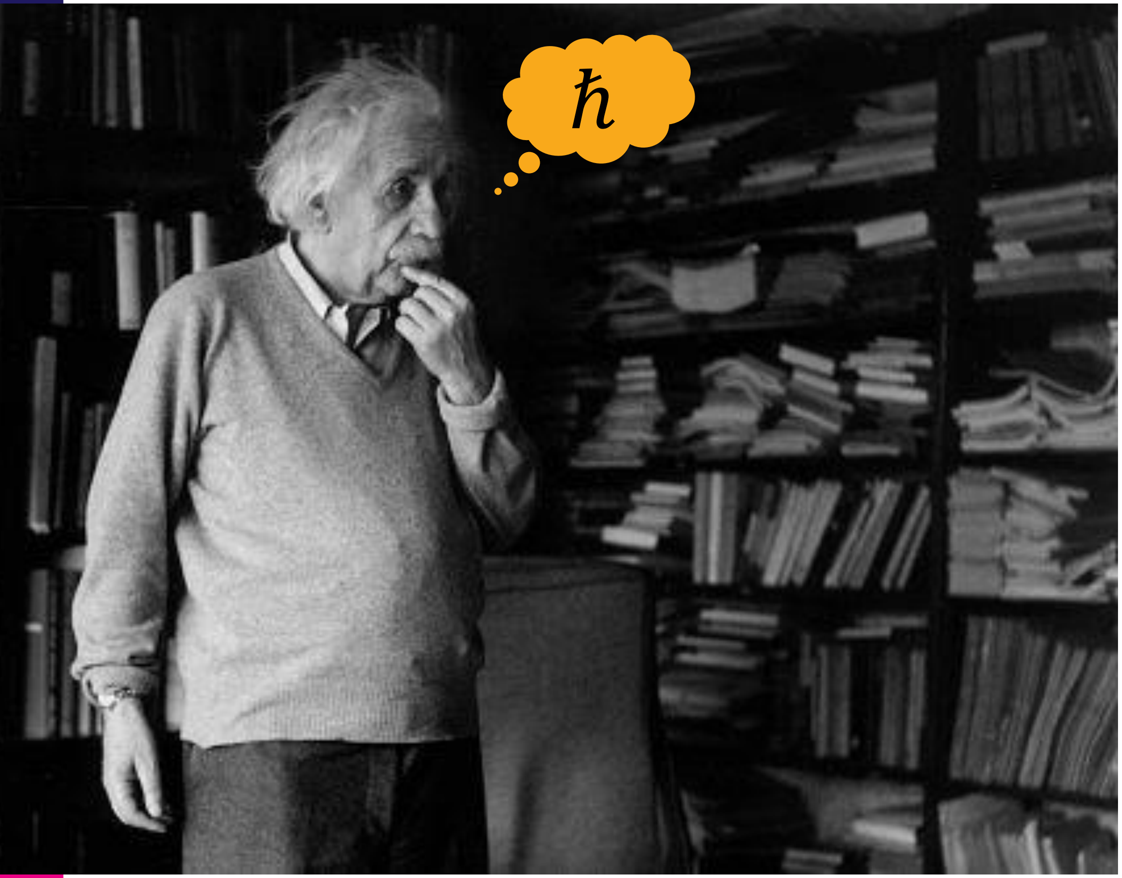
P. Peebles, L. Page, R. Bruce Partridge. Finding the Big Bang.2009

Algo tan feo

¨Desde que introduje este término he tenido mala conciencia.
Pero en aquel momento no pude ver otra manera de contemplar el hecho de la existencia de una densidad media finita de materia. Me pareció verdaderamente feo que la ley del
campo de gravitación estuviera compuesta de dos términos lógicamente independientes y enlazados por una suma. Sobre la justificación de estas impresiones acerca de la simplicidad lógica es difícil argumentar. No puedo evitar sentirlas con fuerza y soy incapaz de creer que se dé en la naturaleza algo tan feo¨

Carta de Einstein a Lemaitre 26 de septiembre de 1947. Documento 15-085.1 de Albert Einstein Archives

Mi mayor error



¨Einstein me comentó hace muchos años que la idea de la repulsión cósmica había sido el mayor error de su vida¨

G. Gamow

G. Gamow. The Evolutionary Universe. Scientific American, september 1956

Mi mayor error

COMMENT

▸ in recognizing the necessity of blunders.

Chemist Linus Pauling knew it. His former postdoc, Jack Dunitz, recalls being told: "Mistakes do no harm in science because there are lots of smart people out there who will immediately spot a mistake and correct it. You can only make a fool of yourself and that does no harm, except to your pride. If it happens to be a good idea, however, and you don't publish it, science may suffer a loss."

KNOTTY PROBLEM

Preposterous ideas can lead to important insights. In 1867, the eminent physicist William Thomson (Lord Kelvin) proposed[3] that atoms were not point-like but 'knotted vortex tubes of the ether'. Ether was the supposed fluid that pervaded space, providing a medium for electricity and magnetism.

Inspired by work on vortices in fluids by the nineteenth-century German physicist Hermann von Helmholtz, Kelvin identified three characteristics of knotted vortex tubes that made them attractive models for atoms.

First, vortices in fluids were astonishingly stable — mirroring to Kelvin the "unalterable distinguishing qualities" of atoms — and each knot could be classed according to its

HISTORY REVISITED

Did Einstein ever say "biggest blunder"?

Almost any history of Albert Einstein's 'cosmological constant' mentions his "biggest blunder"— the introduction of this constant to counteract gravity into equations characterizing the Universe.

Did Einstein actually say this? After scrutinizing dozens of documents while researching my book *Brilliant Blunders* (Simon & Schuster, 2013), I found no evidence that he did.

The "biggest blunder" phrase seems to have come from the colourful physicist George Gamow in an article published in the September 1956 issue of *Scientific American*. Gamow later repeated the story in his 1970 autobiography, *My World Line*.

Einstein was indeed unhappy about having introduced the cosmological constant, saying in a letter to cosmologist Georges Lemaître that he was "unable to believe that such an ugly thing should be realized in nature". Calling it the "biggest blunder" was, in my view, Gamow's hyperbole.

and recombine the four ends in various ways, which can be described using knot theory.

EXTRAORDINARY CLAIMS

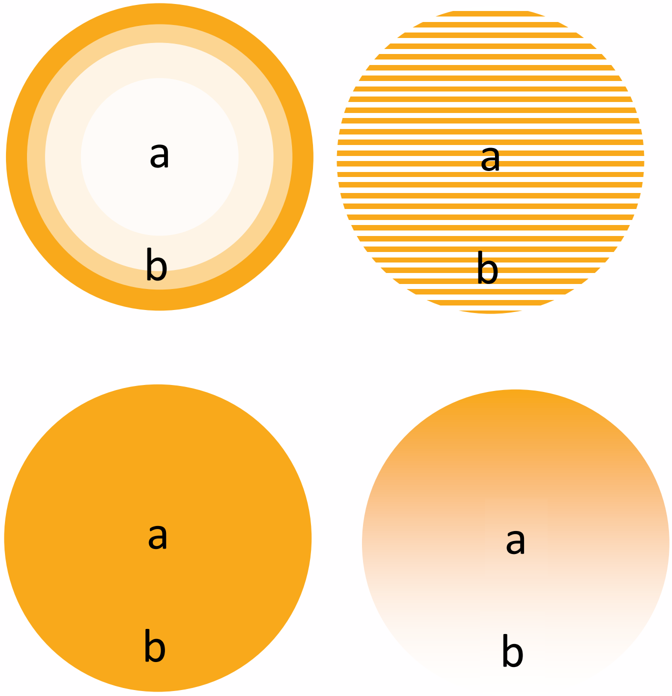
Blunders are sometimes hard to correct. Modern experiments can be so intricate and require such big investments in time and funds that replicating them becomes prohibitive. When a result is widely assumed

impact-driven atmosphere? I believe it must. We should make space for risky scientific proposals in grant and evaluation processes.

Until a decade ago, the committees that allocated observing time on the Hubble Space Telescope were encouraged to give up to 10% of the time to proposals with a low probability of success but potentially high return. A similar philosophy could be

Livio, M. (2013). Lab life: Don't bristle at blunders. Nature, 497(7449), 309-310.

Universo homogéneo e isótropo

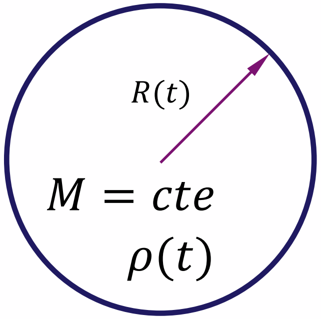


Homogéneo: todos los puntos del espacio tienen las mismas propiedades físicas.

Isótropo: todas las direcciones del espacio con respecto a un punto cualquiera muestran las mismas propiedades físicas y geométricas en cada instante.

E. Kolb and M. Turner. The Early Universe. 1999

Aproximación clásica



$$F = -\frac{GMm}{R^2}$$

$$\ddot{R} = -\frac{GM}{R^2}$$

$$\int \ddot{R}\dot{R}dt = -\int \frac{GM}{R^2}\dot{R}dt$$

$$\frac{\dot{R}^2}{2} = \frac{GM}{R} + U \quad U = cte$$

$$M = cte = \frac{4\pi R^3\rho(t)}{3}$$

para una expansión isotrópica

$$R(t) = a(t)r \quad r = radio\ comóvil$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho(t)}{3} + \frac{2U}{r^2a^2}$$

1ra. ec. de Friedmann

E. Kolb and M. Turner. The Early Universe. 1999

Aproximación clásica

tres soluciones:

$U > 0 \rightarrow \frac{da}{dt} > 0$ siempre distinto de cero, el universo siempre se expandirá

$U < 0 \rightarrow \frac{da}{dt} = 0 \; a_{max} = \sqrt{-Ur/GM}$ la expansión se detendrá y se convertirá en contracción

$$U = 0 \rightarrow \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho(t)}{3} \rightarrow \rho(t) = \frac{3M}{4\pi a^3 r^3}$$

E. Kolb and M. Turner. The Early Universe. 1999

Aproximación clásica

$$dQ = dE + pdV$$ 1ra. Ley Termodinámica

$$dQ = 0$$

$$\dot{E} + p\dot{V} = 0$$

$$V(t) = \frac{4\pi}{3} r^3 a(t)^3$$

$$\dot{V} = 3V\left(\frac{\dot{a}}{a}\right)$$

$$E(t) = V(t)\varepsilon(t)$$

$$\dot{E} = V\left(\dot{\varepsilon} + 3\frac{\dot{a}}{a}\varepsilon\right)$$

$$\dot{\varepsilon} = +3\frac{\dot{a}}{a}\varepsilon + 3\frac{\dot{a}}{a}p = 0$$

utilizando 1ra. ec. de Friedmann y ec. de Einstein

$$2\dot{a}\ddot{a} = \frac{8\pi G}{3c^2}\left(\dot{\varepsilon}a^2 + 2\varepsilon a\dot{a}\right)$$

$$\varepsilon(t) = \rho(t)c^2$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3c^2}(\varepsilon + 3p)$$

2da. ec. de Friedmann

E. Kolb and M. Turner. The Early Universe. 1999

Cte. cosmológica

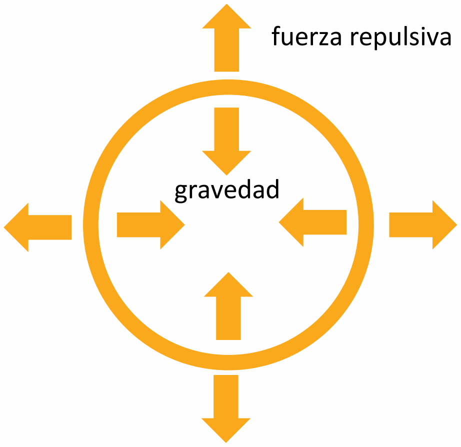
$$\nabla^2\Phi + \Lambda = 4\pi G\rho$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho(t)}{3} + \frac{2U}{r^2a^2} + \frac{\Lambda}{3}$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3c^2}(\varepsilon + 3p) + \frac{\Lambda}{3}$$

$$\varepsilon_\Lambda = \frac{c^2}{8\pi G}\Lambda \qquad p_\Lambda = -\frac{c^2}{8\pi G}\Lambda$$

si $\varepsilon>0$ aceleración negativa.
$p>0$ aporta aceleración negativa.
(universo homogéneo, no hay gradientes de presión)
$p<0$ produce aceleración.



E. Kolb and M. Turner. The Early Universe. 1999

Ecuación de estado

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\varepsilon(t)}{3c^2} + \frac{2U}{r^2a^2}$$ 1ra. ecuación de Friedmann

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3c^2}(\varepsilon + 3p)$$ 2da. ecuación de Friedmann

$a(t), \varepsilon(t), p(t)$ 2 ecuaciones 3 incógnitas

ecuación de estado

$$p = \omega\varepsilon$$

E. Kolb and M. Turner. The Early Universe. 1999