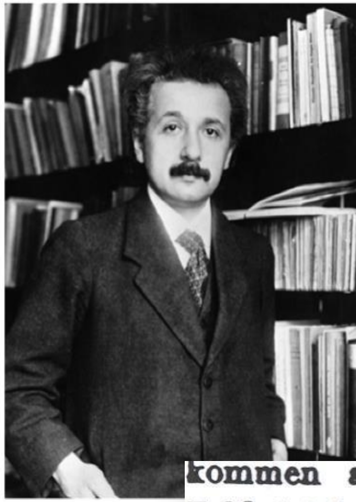
03-07-2014

76/24

Mecánica estadística 2014

Charla 2-Nucleosíntesis

1917

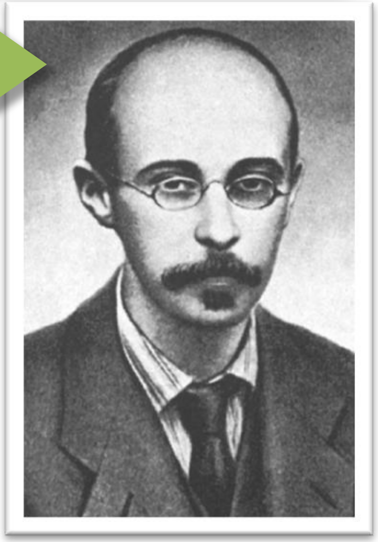


kommen analog ist. Wir können nämlich auf der linken Seite der Feldgleichung (13) den mit einer vorläufig unbekannten universellen Konstante $-\lambda$ multiplizierten Fundamentaltensor $g_{\mu\nu}$ hinzufügen, ohne daß dadurch die allgemeine Kovarianz zerstört wird; wir setzen an die Stelle der Feldgleichung (13)

$$G_{\mu\nu} - \lambda g_{\mu\nu} = -\varkappa\left(T_{\mu\nu} - \frac{1}{2} g_{\mu\nu} T\right). \qquad (13a)$$

Auch diese Feldgleichung ist bei genügend kleinem λ mit den am Sonnensystem erlangten Erfahrungstatsachen jedenfalls vereinbar. Sie befriedigt auch Erhaltungssätze des Impulses und der Energie, denn

1922



Alexander Friedmann

schiedenen Indizes nichts liefern; die Gleichungen (A) für $i = k = 1, 2, 3$ geben eine Beziehung:

$$\frac{R'^2}{R^2} + \frac{2RR''}{R^2} + \frac{c^2}{R^2} - \lambda = 0, \qquad (4)$$

die Gleichung (A) mit $i = k = 4$ liefert die Beziehung:

$$\frac{3R'^2}{R^2} + \frac{3c^2}{R^2} - \lambda = \varkappa c^2 \varrho, \qquad (5)$$

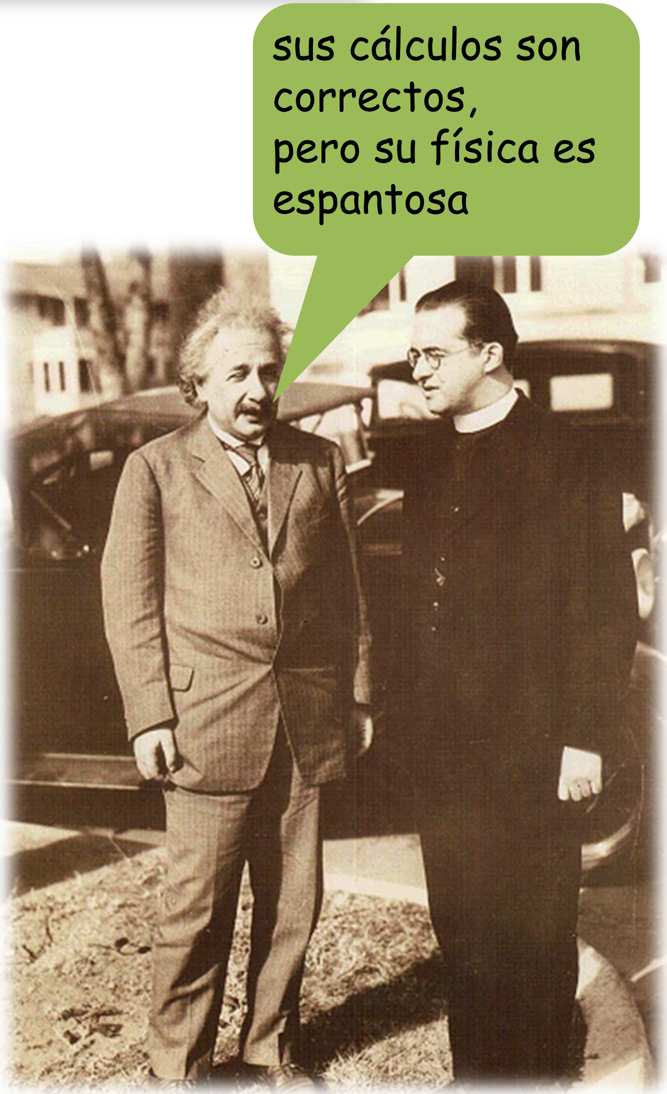
mit

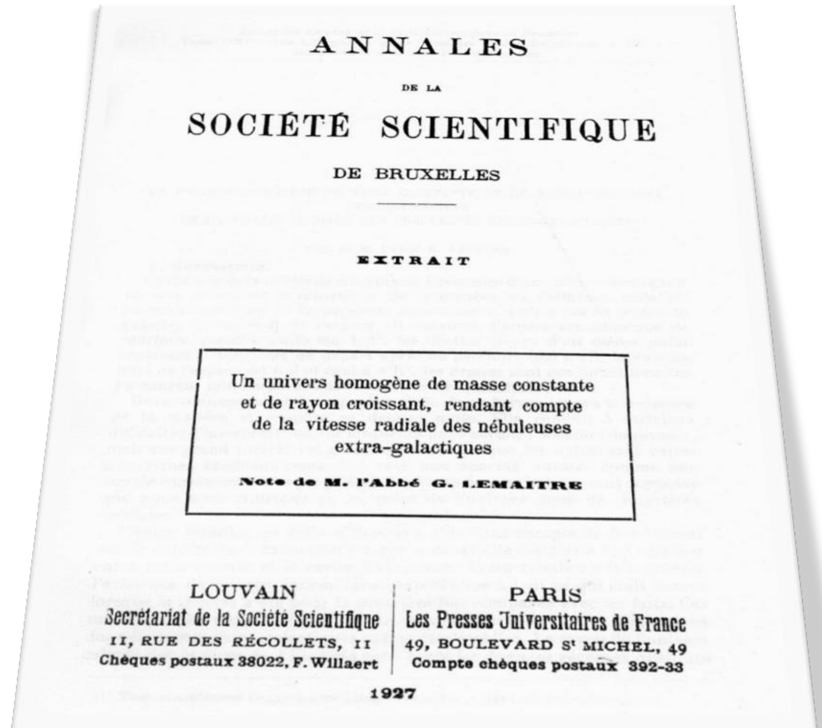
$$R' = \frac{dR}{dx_4} \quad \text{und} \quad R'' = \frac{d^2R}{dx_4^2}.$$

$$\left(\frac{\dot{R}}{R}\right)^2 - \frac{8}{3}\pi G\rho - \frac{1}{3}\Lambda = -\frac{k}{R^2}$$

Alexander Friedmann, “Über die Krümmung des Raumes,” *Zeitschrift für Physik* **10** (1922), 377-386.

1927





ANNALES

DE LA

SOCIÉTÉ SCIENTIFIQUE

DE BRUXELLES

EXTRAIT

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. LEMAITRE

LOUVAIN	PARIS
Secrétariat de la Société Scientifique	Les Presses Universitaires de France
11, RUE DES RÉCOLLETS, 11	49, BOULEVARD S^t MICHEL, 49
Chèques postaux 38022, F. Willaert	Compte chèques postaux 392-33

1927

Lemaître, G. *Ann. Soc. Sci. Brux.* A **47**, 49 (1927).

1930

NEWS | IN FOCUS

huge advantage for astronomers in the state — particularly those at smaller institutions, says Cassio Leandro Barbosa, an astronomer at the University of Paraíba Valley in São Paulo state.

Wendy Freedman, chair of the GMT board and director of the Carnegie Observatories, thinks that São Paulo and the GMT are "a good match". The decision to join will now come down to FAPESP's review of a November 2013 workshop between Brazilian astronomers and the GMT leadership, along with an evaluation of benefits for local industry, says Hernan Chaimovich, special aide to the scientific department at FAPESP. A decision is likely to be made by April, he says.

"Our reputation would drop off a cliff."

According to Chaimovich, FAPESP is also in discussions with the Brazilian Ministry of Science and Technology about a federal contribution to the GMT, which would grant telescope access to investigators outside the state of São Paulo. If the ministry does contribute, ESO advocates could have cause for concern, because that might undercut interest in using the E-ELT, a major driver for Brazil to ratify its ESO membership.

For ESO director-general Tim de Zeeuw, one proposal does not necessarily exclude the other. FAPESP's bid to join the GMT "is independent of the ratification of Brazil to ESO and is very different", he says. Both megatelescopes are a decade or so away from completion, but being part of the ESO gives Brazilian astronomers access to existing observatories in Chile, such as the Atacama Large Millimeter/submillimeter Array and the Very Large Telescope, he adds. "They are cutting-edge facilities available to the Brazilian community here and now."

The ratification process formally began in February last year, but has stalled in Congress. De Zeeuw expects Brazil to confirm the agreement in the first half of 2014, but those familiar with the Brazilian system are less willing to make firm predictions in an election year. Beatriz Barbuy, head of the Astronomical Society of Brazil's ESO committee, is hopeful that the process will wrap up this year. "We will see," she says. "The next step is to find the budget."

Further delays could hurt both ESO and Brazil. Under present rules, major construction contracts for the E-ELT cannot be awarded until Brazil's funds are secure. The country's growing standing in international science would also take a nose dive, says Barbosa, just as it seeks to join other global organizations, such as CERN, Europe's particle-physics laboratory near Geneva, Switzerland. "Our reputation would drop off a cliff," he says. ■

Albert Einstein at Mount Wilson Observatory in 1931, with Edwin Hubble (centre) and Walter Adams.

COSMOLOGY

Einstein's lost theory uncovered

Physicist explored the idea of a steady-state Universe in 1931.

BY DAVIDE CASTELVECCHI

A manuscript that lay unnoticed by scientists for decades has revealed that Albert Einstein once dabbled with an alternative to what we now know as the Big Bang, proposing instead that the Universe expanded steadily and eternally. The recently uncovered work, written in 1931, is reminiscent of a theory championed by British astrophysicist Fred Hoyle nearly 20 years later. Einstein soon abandoned the idea, but the manuscript reveals his continued hesitance to accept that the Universe was created during a single explosive event.

Evidence for the Big Bang first emerged in the 1920s, when US astronomer Edwin Hubble and others discovered that distant galaxies are moving away and that space itself is expanding. This seemed to imply that, in the past, the contents of the observable Universe had been a very dense and hot 'primordial broth'.

But, from the late 1940s, Hoyle argued that space could be expanding eternally and keeping a roughly constant density. It could do this by continually adding new matter, with elementary particles spontaneously popping up from space, Hoyle said. Particles would then coalesce to form galaxies and stars, and these would appear at just the right rate to take up the extra room created by the expansion of space. Hoyle's Universe was always infinite, so its size did not change as it expanded. It was in a 'steady state'.

The newly uncovered document shows that Einstein had described essentially the same idea much earlier. "For the density to remain constant new particles of matter must be continually formed," he writes. The manuscript is thought to have been produced during a trip to California in 1931 — in part because it was written on American note paper.

It had been stored in plain sight at the Albert Einstein Archives in Jerusalem — and is freely available to view on its website — but had been mistakenly classified as a first draft of another Einstein paper. Cormac O'Raifeartaigh, a physicist at the Waterford Institute of Technology in Ireland, says that he "almost fell out of his chair" when he realized what the manuscript was about. He and his collaborators have posted their findings, together with an English translation of Einstein's original German manuscript, on the arXiv preprint server (C. O'Raifeartaigh et al. Preprint at http://arxiv.org/abs/1402.0132;

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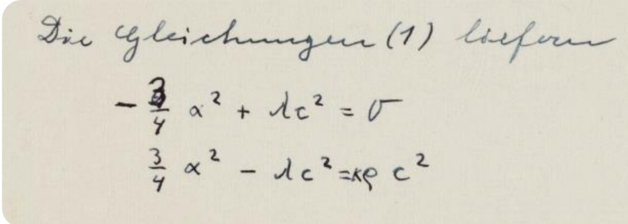


Davide Castelvecchi. Einstein's lost theory uncovered. Nature 506, 418–419 (27 February 2014)

Corrimiento al rojo

$$z = \frac{\lambda_0 - \lambda}{\lambda}$$

$z = corrimiento\ al\ rojo$

$\lambda_0 = longitud\ de\ onda\ referencia$

$\lambda = longitud\ de\ onda\ medida$

$$\lambda_0 > \lambda$$

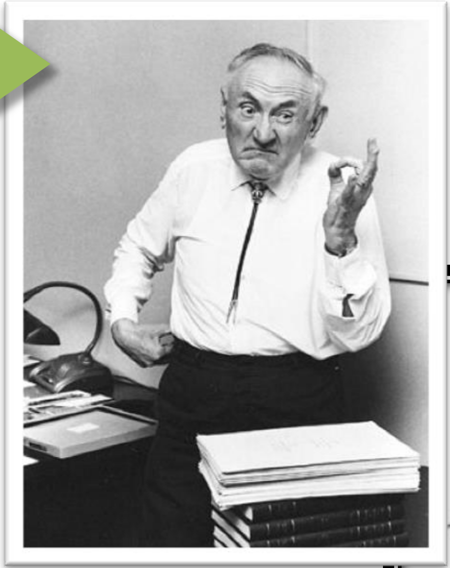
$$z = kD = \left(\frac{H_0}{c}\right) D$$

Año	H_0 (Km/s/Mpc)	Método
1929	530	Cefeidas
1954	263	Recalibración Cefeidas
1996	56	Luminosidad de galaxias
2001	72	HST

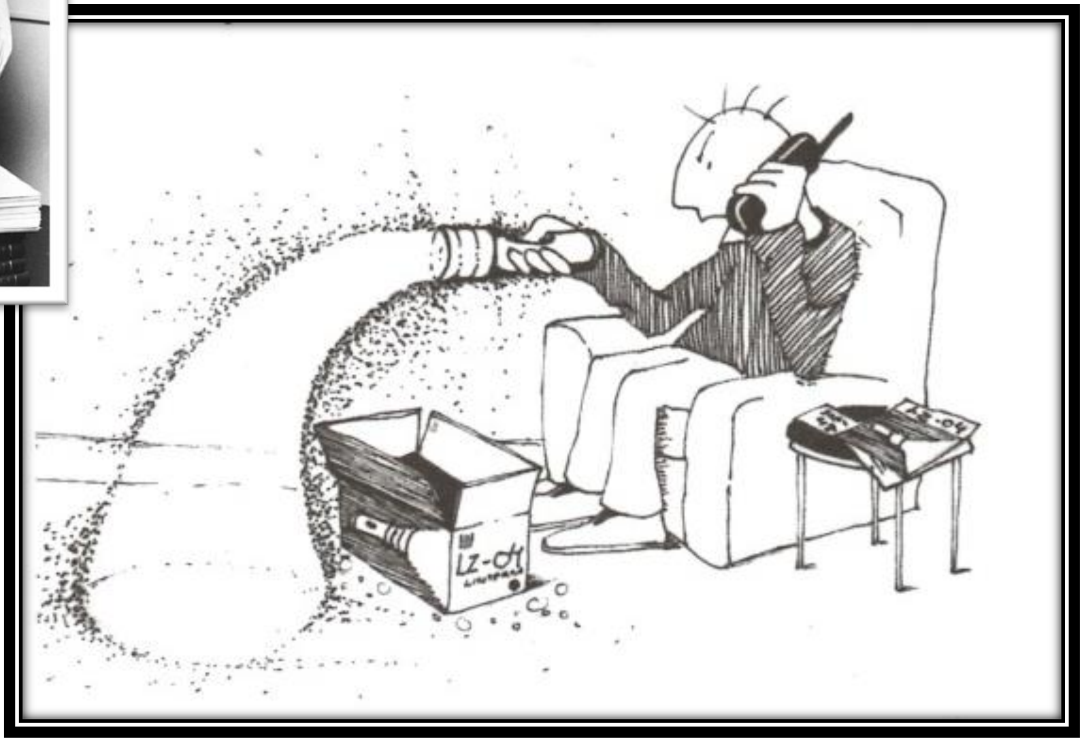
$${H_0}^{-1} \approx edad\ del\ universo$$

$$H_0 \approx 72\left(\frac{km}{s\ Mpc}\right) \approx 13{,}7x10^9 años$$

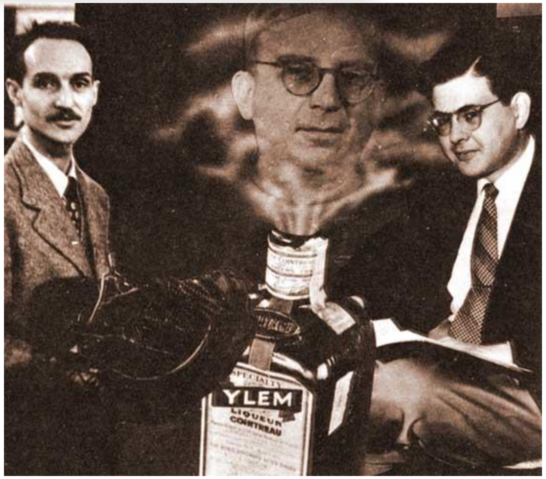
Teoría de la luz cansada



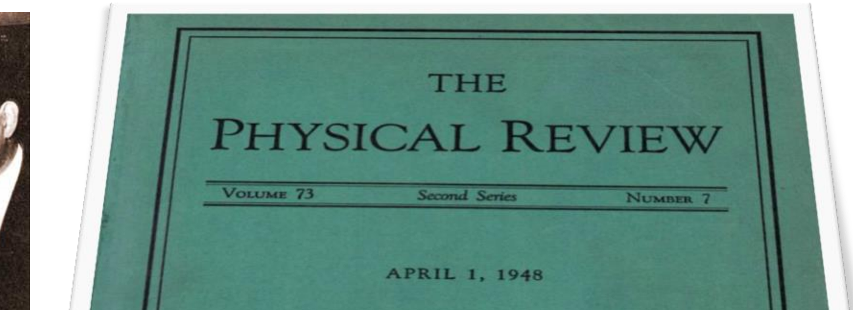
Fritz Zwicky

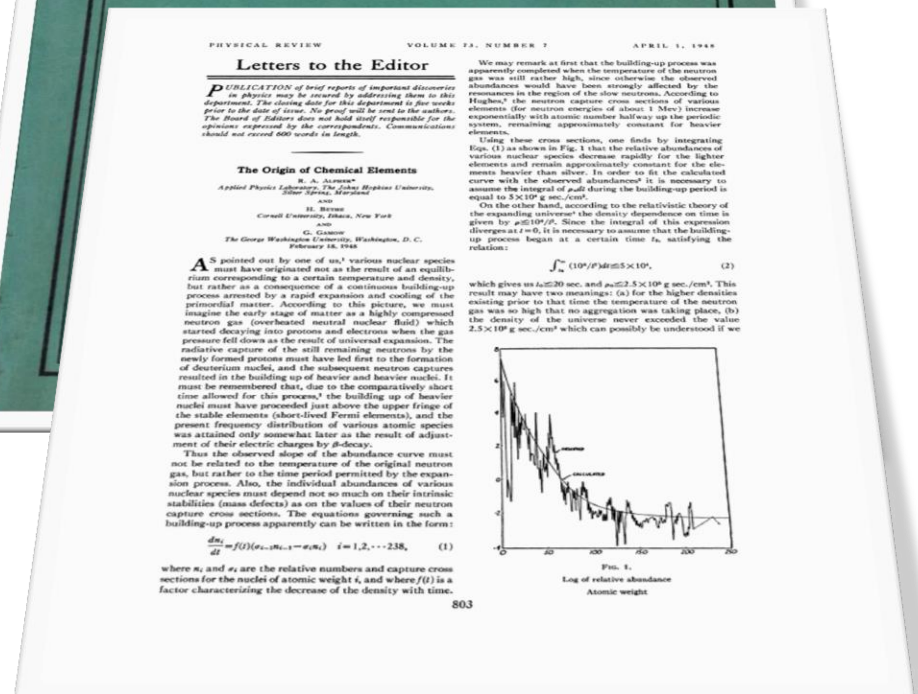


1948



Robert Herman
George Gamow
Ralph Alpher





PHYSICAL REVIEW VOLUME 73, NUMBER 7 APRIL 1, 1948

Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is five weeks prior to the date of issue. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length.

The Origin of Chemical Elements

R. A. ALPHER*
Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland
AND
H. BETHE
Cornell University, Ithaca, New York
AND
G. GAMOW
The George Washington University, Washington, D. C.
February 18, 1948

AS pointed out by one of us,[1] various nuclear species must have originated not as the result of an equilibrium corresponding to a certain temperature and density, but rather as a consequence of a continuous building-up process arrested by a rapid expansion and cooling of the primordial matter. According to this picture, we must imagine the early stage of matter as a highly compressed neutron gas (overheated neutral nuclear fluid) which started decaying into protons and electrons when the gas pressure fell down as the result of universal expansion. The radiative capture of the still remaining neutrons by the newly formed protons must have led first to the formation of deuterium nuclei, and the subsequent neutron captures resulted in the building up of heavier and heavier nuclei. It must be remembered that, due to the comparatively short time allowed for this process,[2] the building up of heavier nuclei must have proceeded just above the upper fringe of the stable elements (short-lived Fermi elements), and the present frequency distribution of various atomic species was attained only somewhat later as the result of adjustment of their electric charges by β-decay.

Thus the observed slope of the abundance curve must not be related to the temperature of the original neutron gas, but rather to the time period permitted by the expansion process. Also, the individual abundances of various nuclear species must depend not so much on their intrinsic stabilities (mass defects) as on the values of their neutron capture cross sections. The equations governing such a building-up process apparently can be written in the form:

$$\frac{dn_i}{dt}=f(t)(\sigma_{i-1}n_{i-1}-\sigma_i n_i) \quad i=1,2,\cdots 238, \qquad (1)$$

where n_i and σ_i are the relative numbers and capture cross sections for the nuclei of atomic weight i, and where $f(t)$ is a factor characterizing the decrease of the density with time.

We may remark at first that the building-up process was apparently completed when the temperature of the neutron gas was still rather high, since otherwise the observed abundances would have been strongly affected by the resonances in the region of the slow neutrons. According to Hughes,[3] the neutron capture cross sections of various elements (for neutron energies of about 1 Mev) increase exponentially with atomic number halfway up the periodic system, remaining approximately constant for heavier elements.

Using these cross sections, one finds by integrating Eqs. (1) as shown in Fig. 1 that the relative abundances of various nuclear species decrease rapidly for the lighter elements and remain approximately constant for the elements heavier than silver. In order to fit the calculated curve with the observed abundances[4] it is necessary to assume the integral of $\rho_n dt$ during the building-up period is equal to 5×10^4 g sec./cm^3.

On the other hand, according to the relativistic theory of the expanding universe[5] the density dependence on time is given by $\rho\cong10^6/t^2$. Since the integral of this expression diverges at $t=0$, it is necessary to assume that the building-up process began at a certain time t_0, satisfying the relation:

$$\int_{t_0}^{\infty}(10^6/t^2)dt\cong5\times10^4, \qquad (2)$$

which gives us $t_0\cong20$ sec. and $\rho_n\cong2.5\times10^4$ g sec./cm^3. This result may have two meanings: (a) for the higher densities existing prior to that time the temperature of the neutron gas was so high that no aggregation was taking place, (b) the density of the universe never exceeded the value 2.5×10^4 g sec./cm^3 which can possibly be understood if we

FIG. 1.
Log of relative abundance
Atomic weight

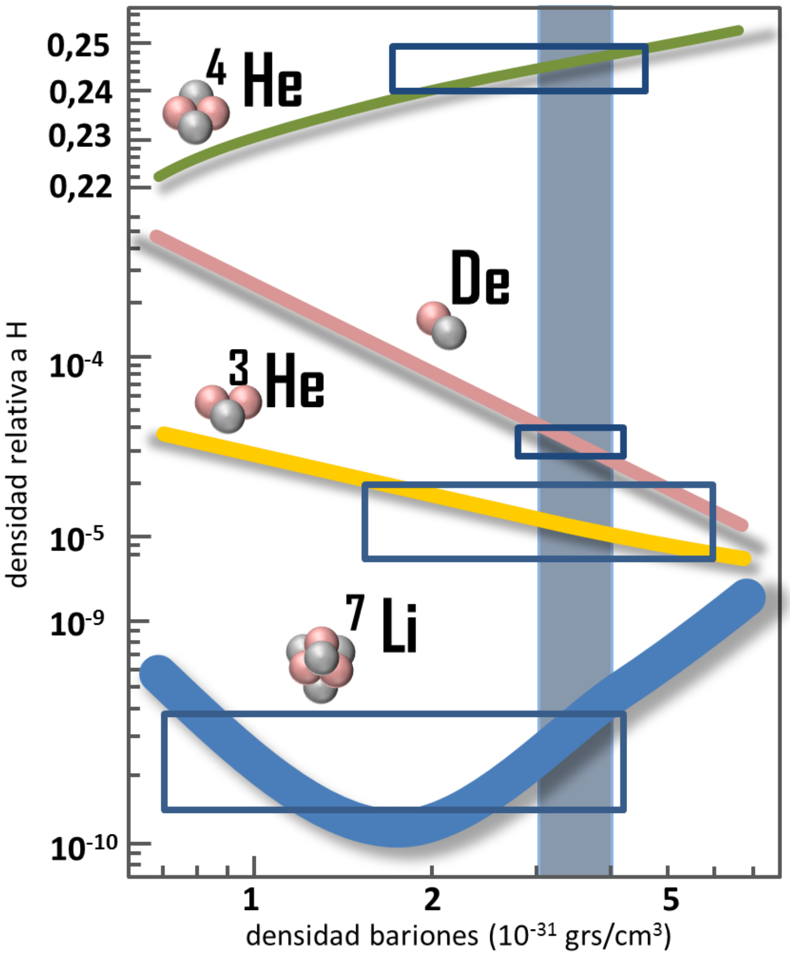
803

Alpher, R. A.; Bethe, H.; Gamow, G. The Origin of Chemical Elements. Physical Review 73 (7): 803–804. (1 April 1948).

1964

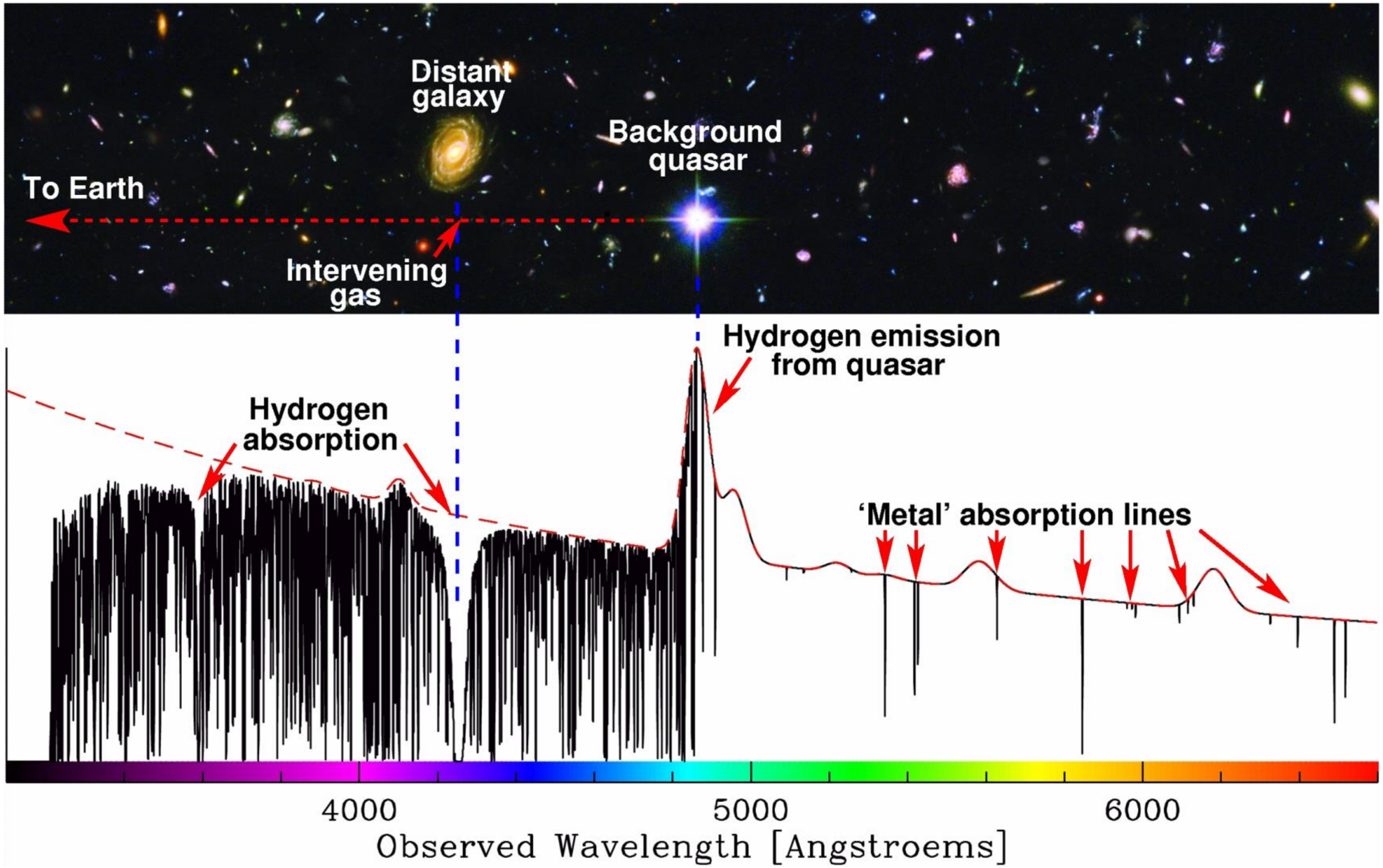
Penzias, A. A.; Wilson, R. W. A Measurement of Excess Antenna Temperature at 4080 Mc/s. Astrophysical Journal, vol. 142, p.419-421.1965

Abundancia relativa de elementos



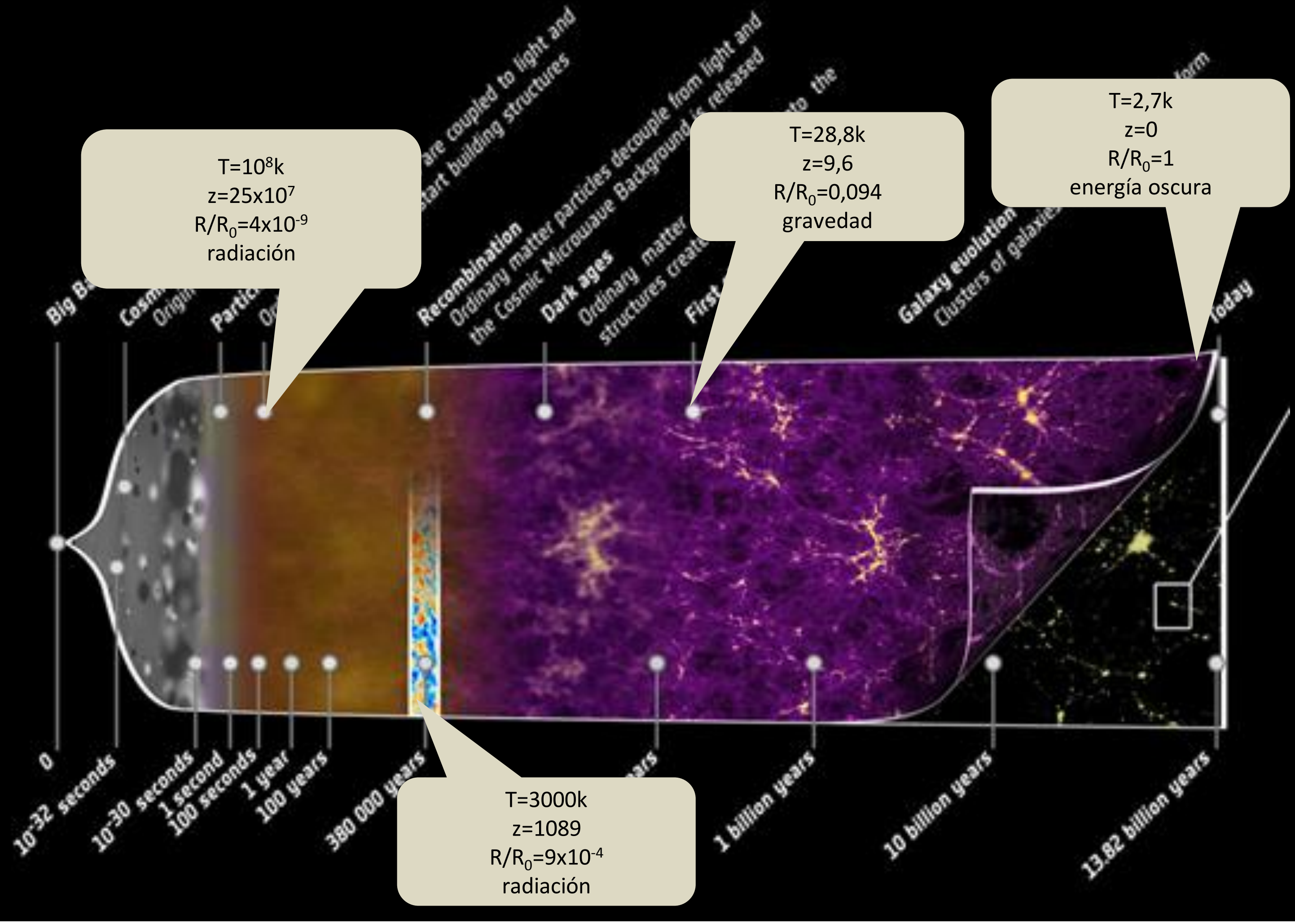
B Scott Burles, Kenneth M. Nollett and Michael S. Turner. BIG BANG NUCLEOSYNTHESIS PREDICTIONS FOR PRECISION COSMOLOGY. The Astrophysical Journal, 552:L1–L5, 2001 May 1

Abundancia relativa de elementos

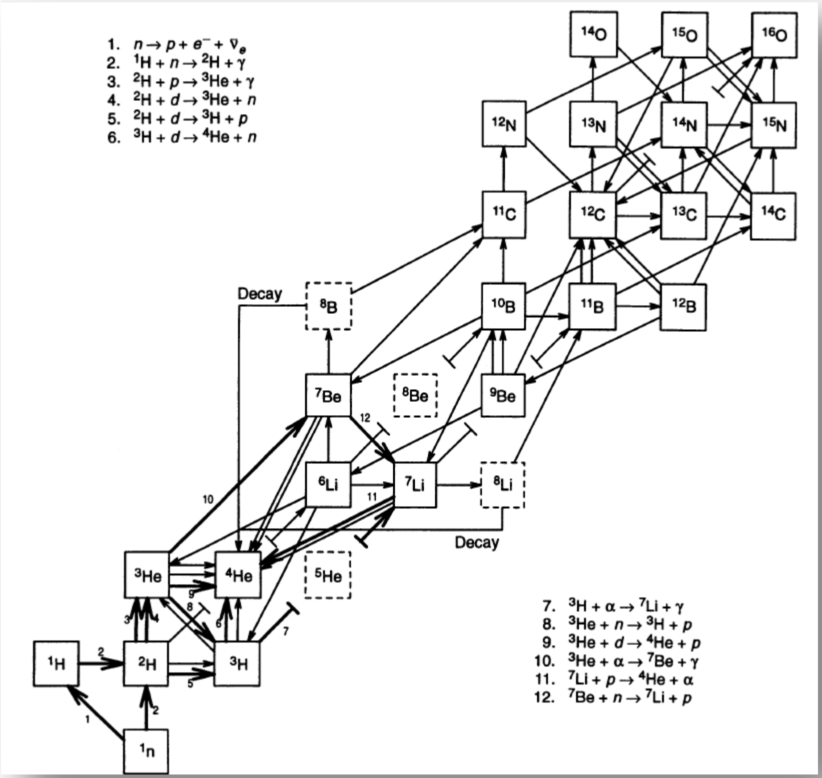


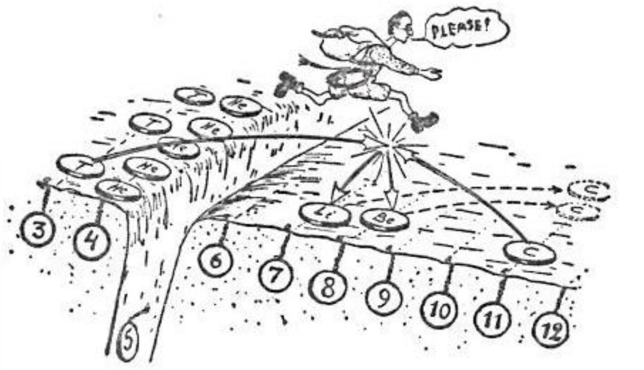
Schramm, D. N. and Turner M. S. Rev. Mod. Phys, 70,303. 1998

Across the Universe



nucleosíntesis





- **76%** protones libres
- **24%** ^4He
- $4x10^{-5}$ D
- 10^{-5} ^3He
- 10^{-9} ^7Be
- 10^{-10} ^7Li

CJ Copi, DN Schramm, MS Turner. Big-bang nucleosynthesis and the baryon density of the universe. Science Vol. 267 no. 5195 pp. 192-199. 1997

nucleosíntesis

- t=0,1seg
- $T=3x10^{10}$ K
- energía x fotón =10 Mev

Temp. del núcleo del sol~$1,36 \times 10^7$ K

Ionización de H =13,6 eV
Ligazón D=2,2Mev
LHC=7TeV

$$n + \nu_e \leftrightarrow p + e^-$$

$$n + e^+ \leftrightarrow p + \overline{\nu_e}$$

nucleosíntesis

$$n + \nu_e \leftrightarrow p + e^-$$

$$n + e^+ \leftrightarrow p + \overline{\nu_e}$$

$$n_n = g_n \left(\frac{m_n kT}{2\pi\hbar^2}\right)^{3/2} \exp[-\frac{m_n c^2}{kT}]$$

$$n_p = g_p \left(\frac{m_p kT}{2\pi\hbar^2}\right)^{3/2} \exp[-\frac{m_p c^2}{kT}]$$

$$g_n = g_p = 2$$

$$\frac{n_n}{n_p} = \left(\frac{m_n}{m_p}\right)^{3/2} \exp[\frac{m_n - m_p}{kT}]c^2$$

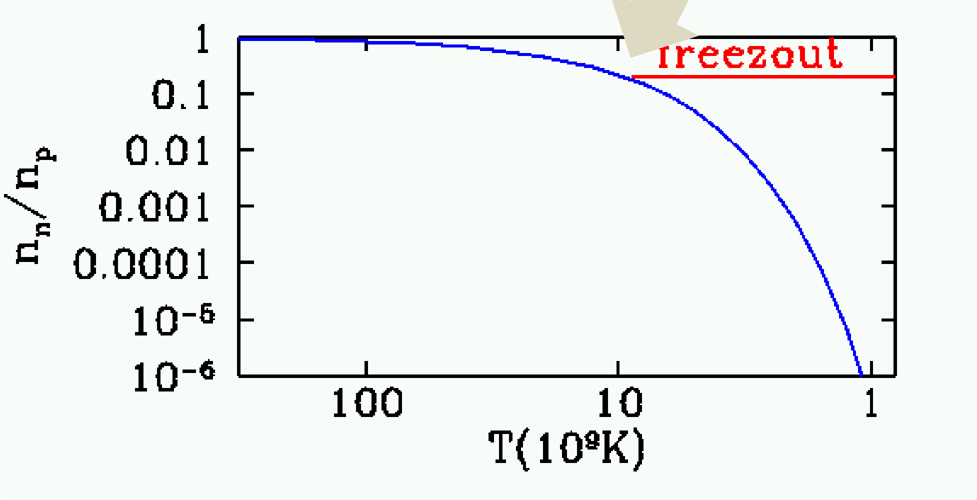
$$m_n \sim m_p$$

$$(m_n - m_p)c^2 = Q_n = 1{,}29 Mev$$

nucleosíntesis

$$\frac{n_n}{n_p} = \exp[-\frac{Q_n}{kT}]$$

$$\frac{n_n}{n_p} = 0{,}2$$



T>>1,5x10[10] K

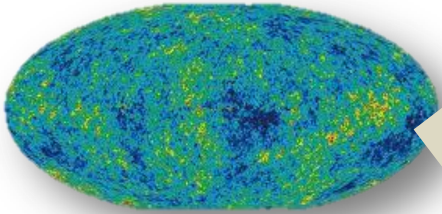
t<<1 seg

$n_p \approx n_n$

$kT \sim 0{,}8 Mev$

$T_{freez} \approx 9x10^9 K$

$desacople \approx 2seg$



$T = 1{,}95K$

$fondo$ cósmico de neutrinos (CNB)

nucleosíntesis

$T_{freez} \approx 9x10^9K$

$desacople \approx 2seg$

$$\frac{n_n}{n_p} = 0{,}2$$

$$p + p \leftrightarrow D + e^+ + \nu_e$$

$$n + n \leftrightarrow D + e^- + \bar{\nu_e}$$

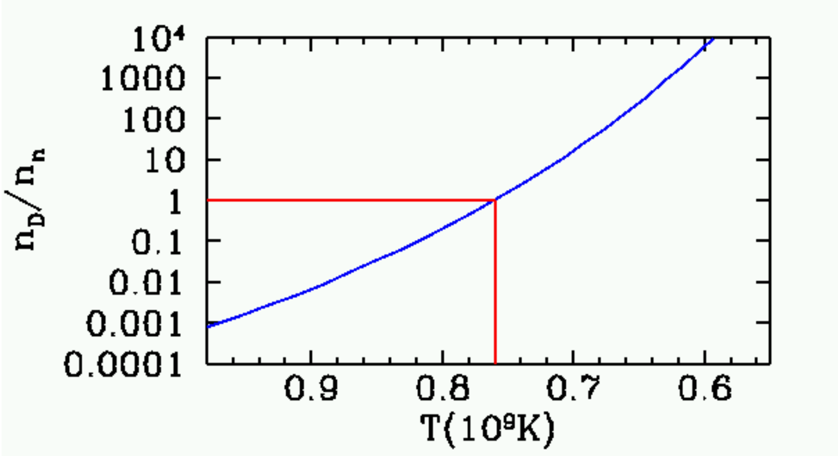
$$p + n \leftrightarrow D + \gamma$$

$$energía\ liberada\ B_D = (m_n + m_p - M_D)c^2 = 2{,}22Mev$$

$$\frac{n_D}{n_p n_n} = \frac{g_D}{g_p g_n}\left(\frac{m_D}{m_p m_D}\right)^{3/2}\left(\frac{kT}{2\pi\hbar^2}\right)^{-3/2}\exp[\frac{[m_p + m_n - m_D]c^2}{kT}]$$

$$\frac{n_D}{n_n} \approx 6{,}5\eta\left(\frac{kT}{m_n c^2}\right)^{\frac{3}{2}}\exp[\frac{B_D}{kT}]$$

nucleosíntesis



$$\frac{n_D}{n_n} \approx 6{,}5\eta \left(\frac{kT}{m_n c^2}\right)^{\frac{3}{2}} \exp[\frac{B_D}{kT}]$$

$kT \sim 0{,}066 Mev$

$T_{nuc} \approx 7{,}6x10^8 K$

$tiempo \approx 200seg$

nucleosíntesis

$$D + p \leftrightarrow {}^3He + \gamma$$

$$D + n \leftrightarrow {}^3H + \gamma$$

$$D + D \leftrightarrow {}^3He + n$$

$$D + D \leftrightarrow {}^3H + p$$

$$D + D \leftrightarrow {}^4He + \gamma$$

$${}^3H + p \leftrightarrow {}^4He + \gamma$$

$${}^3He + n \leftrightarrow {}^4He + \gamma$$

$${}^3H + D \leftrightarrow {}^4He + n$$

$${}^3He + D \leftrightarrow {}^4He + p$$

$${}^4He + D \leftrightarrow {}^6Li + \gamma$$

$${}^4He + {}^3H \leftrightarrow {}^7Li + \gamma$$

$${}^4He + {}^3He \leftrightarrow {}^7Be + \gamma$$

$${}^4He + {}^4He \leftrightarrow {}^8Be$$

vida media $3x10^{-16}$ seg

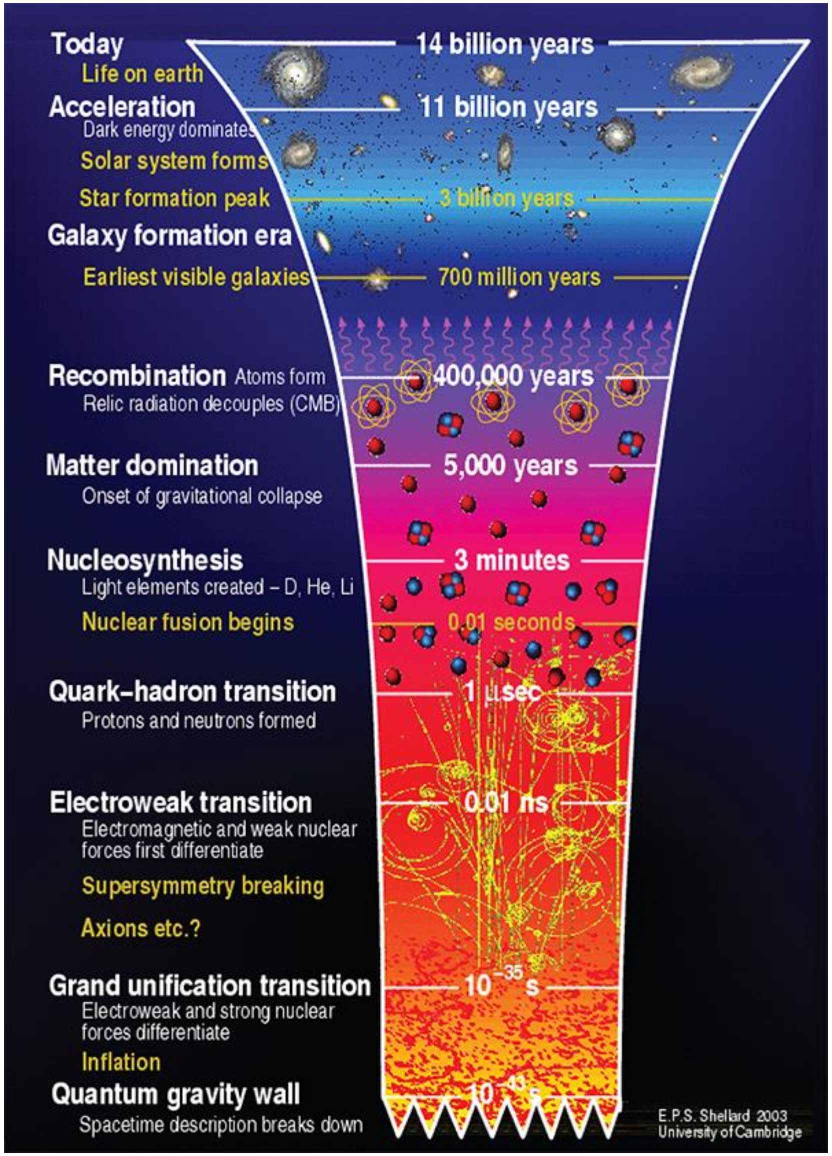
nucleosíntesis

$$\frac{n_n}{n_p} = 0{,}2 * \exp[-t/\tau] \approx 0{,}13$$

Vida media del neutrón
890seg

$$\frac{4n_{^4He}}{n_b} \cong \frac{4\left(\frac{n_n}{2}\right)}{n_p + n_n} = \frac{2\left(\frac{n_n}{n_p}\right)}{1 + \left(\frac{n_n}{n_p}\right)} = 0{,}23$$

$$0{,}241 \pm 0{,}002$$


Today
Life on earth
Acceleration
Dark energy dominates
Solar system forms
Star formation peak
Galaxy formation era
Earliest visible galaxies
Recombination Atoms form
Relic radiation decouples (CMB)
Matter domination
Onset of gravitational collapse
Nucleosynthesis
Light elements created – D, He, Li
Nuclear fusion begins
Quark–hadron transition
Protons and neutrons formed
Electroweak transition
Electromagnetic and weak nuclear forces first differentiate
Supersymmetry breaking
Axions etc.?
Grand unification transition
Electroweak and strong nuclear forces differentiate
Inflation
Quantum gravity wall
Spacetime description breaks down
14 billion years
11 billion years
3 billion years
700 million years
400,000 years
5,000 years
3 minutes
0.01 seconds
1 µsec
0.01 ns
10^{-35} s
10^{-43} s
E.P.S. Shellard 2003
University of Cambridge

«Cada vez que me encuentro con alguien que no da crédito al Big Bang, me gusta enseñarle la figura siguiente, que guardo en una tarjeta en mi billetera. Y entonces digo: ¡Ya lo ve !. ¡Si que hubo un Big Bang!»

Lawrence M. Krauss. El universo de la nada.