

# Fondo de radiación cósmico

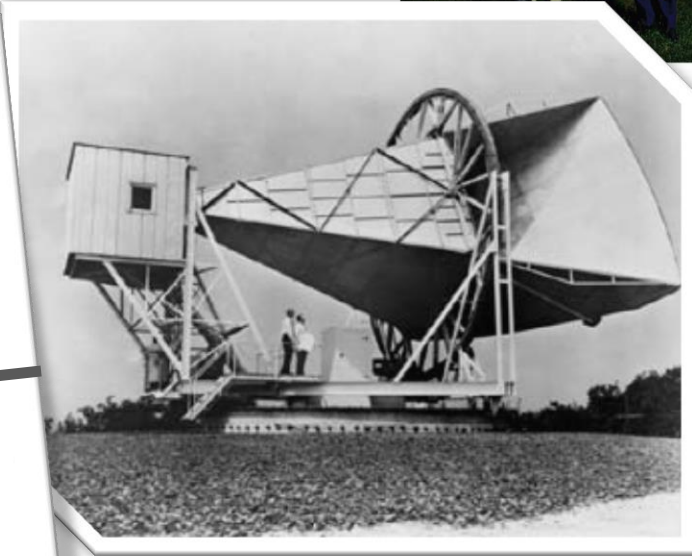
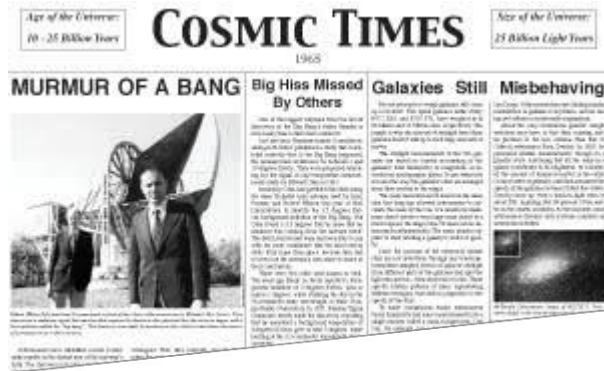


Pezzutti Aldo  
Mecánica estadística

27/6/2013

# Descubrimiento del fondo de radiación

1965



**A MEASUREMENT OF EXCESS ANTENNA TEMPERATURE AT 4080 Mc/s**

Measurements of the effective zenith noise temperature of the 20-foot horn-reflector antenna (Crawford, Hogg, and Hunt 1961) at the Crawford Hill Laboratory, Holmdel, New Jersey, at 4080 Mc/s have yielded a value about 3.5° K higher than expected. This excess temperature is, within the limits of our observations, isotropic, unpolarized, and

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Vol. 142

**LETTERS TO THE EDITOR**

420 free from seasonal variations (July, 1964–April, 1965). A possible explanation for the observed excess noise temperature is the one given by Dicke, Peebles, Roll, and Wilkinson (1965) in a companion letter in this issue.



**Penzias A. A., Wilson R. W. A measurement of excess antenna temperature at 4080mc/s. Astrophysical Journal 142-419(1965)**



# Descubrimiento del fondo de radiación

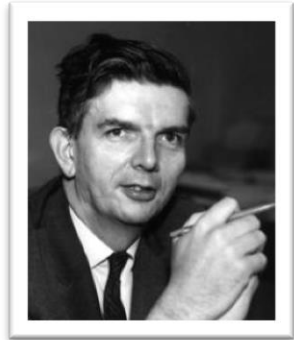
1965

## COSMIC BLACK-BODY RADIATION\*

One of the basic problems of cosmology is the singularity characteristic of the familiar cosmological solutions of Einstein's field equations. Also puzzling is the presence of matter in excess over antimatter in the universe, for baryons and leptons are thought to be conserved. Thus, in the framework of conventional theory we cannot understand the origin of matter or of the universe. We can distinguish three main attempts to deal with these problems.

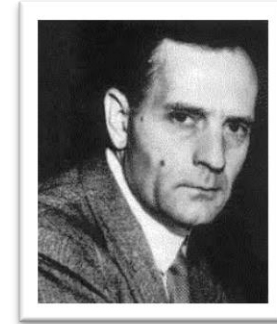
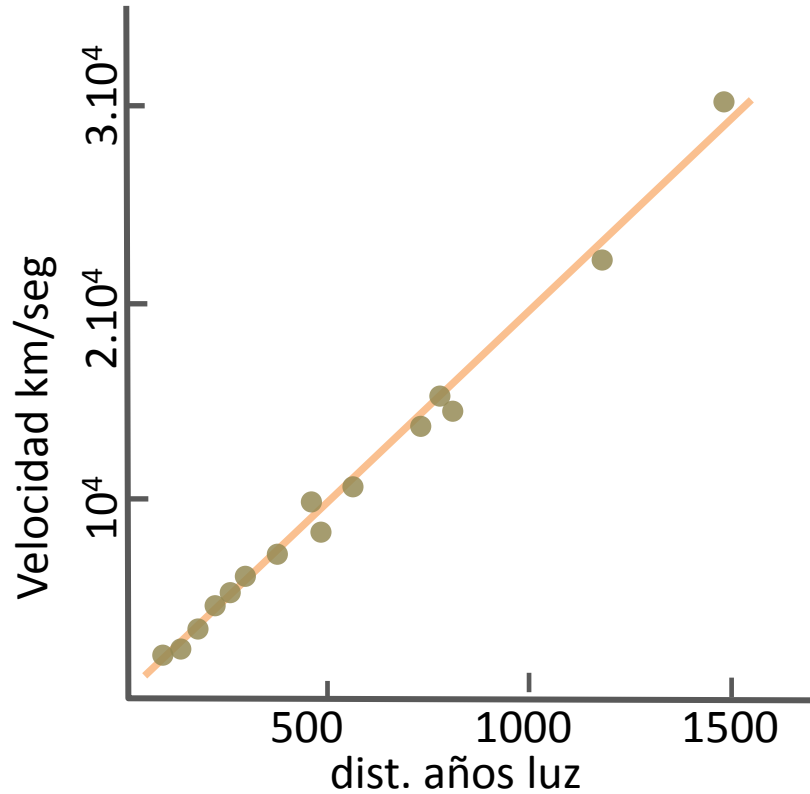
1. The assumption of continuous creation (Bondi and Gold 1948; Hoyle 1948), which avoids the singularity by postulating a universe expanding for all time and a continuous but slow creation of new matter in the universe.
2. The assumption (Wheeler 1964) that the creation of new matter is intimately related to the existence of the singularity, and that the resolution of both paradoxes may be found in a proper quantum mechanical treatment of Einstein's field equations.
3. The assumption that the singularity results from a mathematical over-idealization,

\* This research was supported in part by the National Science Foundation and the Office of Naval Research of the U.S. Navy.



# Expansión del universo-Ley de Hubble

1929



$$z = \frac{\lambda_1 - \lambda_2}{\lambda_1} = \frac{H_0}{c} D$$

$$v = HD$$

**E. Hubble.** *A relation between distance and radial velocity among extra-galactic nebulae.* PNAS. **15** 168-173.(1929).

# Descubrimiento del fondo de radiación

1935

Adams y Dunham

Análisis espectral de las ondas de radio emitidas por gas interestelar 2,3K

1950

T. Shmaonov  
P. Le Roux  
W.K.Rose

Radio astronomía 3K

# Descubrimiento del fondo de radiación

1948

## 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

G. Gamow  
The George Washington University, Washington, D. C.  
February 18, 1948

As pointed out by one of our 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 build-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, 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  $\beta$ -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 build-up process apparently can be written in the form:

$$\frac{dN_i}{dt} = \sum_{j=1}^{i-1} \lambda_{ij} N_j - \lambda_i N_i \quad (1)$$

where  $\lambda_{ij}$  and  $\lambda_i$  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.

given by  $\lambda_{ij} = \lambda_{ij} f(t)$ . Since the integral of this expression is  $\int_0^t f(t) dt$ , it is necessary to assume that the build-up process began at a certain time  $t_0$ , satisfy relation:

$$\int_{t_0}^{\infty} f(t) dt = 10^9 \text{ sec.}$$

which gives us  $t_0 = 2.0 \times 10^9$  sec. and  $\rho_0 = 2.5 \times 10^6 \text{ g./cc.}$  This result may have two meanings: (a) for the higher density existing prior to that time the temperature of the gas was so high that no aggregation was taking place; the density of the universe never exceeded the  $2.5 \times 10^6 \text{ g./cc.}$  which can possibly be understood

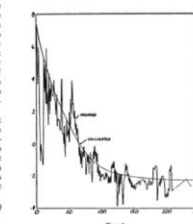


Fig. 1. Log of relative abundance versus atomic weight.

APP

that the building-up in the temperature  $T$ , since otherwise it has been strongly affected by the slow neutron capture cross sections (which are of the order of  $1 \text{ M.}$  in a number of half-way up) is approximately constant. It shows, one finds by (1) that the relative abundances decrease rapidly for  $i$  approximately constant  $f(t)$ . In order to fit the observed abundances it is necessary during the building-up period to the relative abundance  $N_i$ .

804

### LETTERS TO THE EDITOR

use the new type of cosmological solutions involving the angular momentum of the expanding universe (spinning universes).<sup>1</sup> More detailed studies of Eq. (1) leading to the observed abundance curve and discussion of further consequences will be published by one of us (R. A. Alpher) in due course.

\* A portion of the work described in this paper has been suggested by the Bureau of Ordnance, U. S. Navy, under Contract N00013-46-0-1000, and is published by permission of the Chief of Naval Operations. The authors are: R. A. Alpher, J. H. Gamow, and G. Gamow. *Physical Review*, 73, 803 (1948).

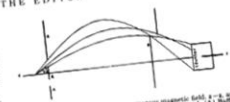


Fig. 2. Paths of electrons in a homogeneous magnetic field. A - solid angle of emission;  $\theta$  - azimuthal angle of electron;  $\phi$  - deflection defining range of  $\theta$ . (R. A. Alpher).

### A Beta-Ray Spectrometer Design of Quadratic Resolution-Solid Angle Relationship

Frank and Nelson, Los Angeles, California  
February 18, 1948

In a  $\beta$ -spectrometer for use with low intensity sources it is advantageous to collect electrons emitted by the source in as large a solid angle consistent with the required resolution. In conventional spectrometers the momentum of the emitted electrons is proportional to the momentum of the source. For small  $\Delta\theta$  ( $\Delta\theta$  is the half-intensity width observed for a point source of monoenergetic electrons), the double focusing spectrometer<sup>1</sup> has a more favorable proportionality constant than the constant field magnetic (Witcher<sup>2</sup>) spectrometer. The thin-plate spectrometer has a still less favorable constant. Figure 1 shows approximate  $\Delta\theta$  vs.  $\Delta E$  curves for these designs. The double focusing spectrometer<sup>1</sup> brings monoenergetic rays having nearly the same initial angles with the axis,  $\gamma$ , to a "ring-focus" (Fig. 2). By placing baffles inside and outside this ring-focus the resolution may be improved without decreasing it. The resolution attainable is approximately that shown in Fig. 1 for rays with  $30^\circ < \gamma < 60^\circ$ , somewhat poorer outside this range. For

small  $\Delta\theta$ ,  $\Delta\theta = 0.03^\circ$ . Since the improvement in resolution attainable in this way seems not to be widely appreciated, it may be useful to direct attention to it.

Changing the energy of the electrons (or the field strength) without changing the range of  $\gamma$  uniformly expands or contracts the paths shown in Fig. 2 about the source as the fixed point. The best resolution is therefore obtained by placing the ring-focus baffles so that their defocusing edges lie on a cone with vertex at the source and defining edges lie on a cone with vertex at the source and axis parallel to the magnetic field.

It seems likely that a similar ring-focus exists in a thin-plate spectrometer and has similar favorable properties. Thus it is probably possible to combine the copper and poorer efficiency of the thin-plate design with a favorable resolution vs. solid angle curve. The position and properties of this ring-focus could be found experimentally (e.g., by numerical integration of the electron path equations).

The source diameter just sufficient to impair the momentum resolution is of the order of  $(10/2\pi)$  times (radius of curvature) for the solenoid spectrometer either with or without the ring-focus baffles. Thus when an extended source is desirable (e.g., with a source of low specific activity) the improvement in counting rate at fixed resolution shown in Fig. 2 is genuine, while the improvement in resolution at fixed counting rate is in part spurious.

<sup>1</sup> H. W. W. Wickham and R. A. Alpher, *Physical Review*, 73, 803 (1948).  
<sup>2</sup> E. M. Wickham, *Physical Review*, 73, 803 (1948).  
<sup>3</sup> E. M. Wickham, *Physical Review*, 73, 803 (1948).

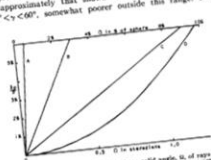


Fig. 1. Minimum resolution,  $\Delta E$ , vs. solid angle,  $\Delta\theta$ , of rays used. (A) Thin-plate spectrometer; (B) Solenoid spectrometer; (C) Double focusing spectrometer. All curves are approximate and refer only to a point source.

### The Hard Component of Cosmic Radiation as Affected by the Variation in Air Mass Distribution with Latitude

KENNETH M. ECKHART  
Department of Physics, New York University, New York  
Silver Laboratory, Inc., Flushing, New York  
February 26, 1948

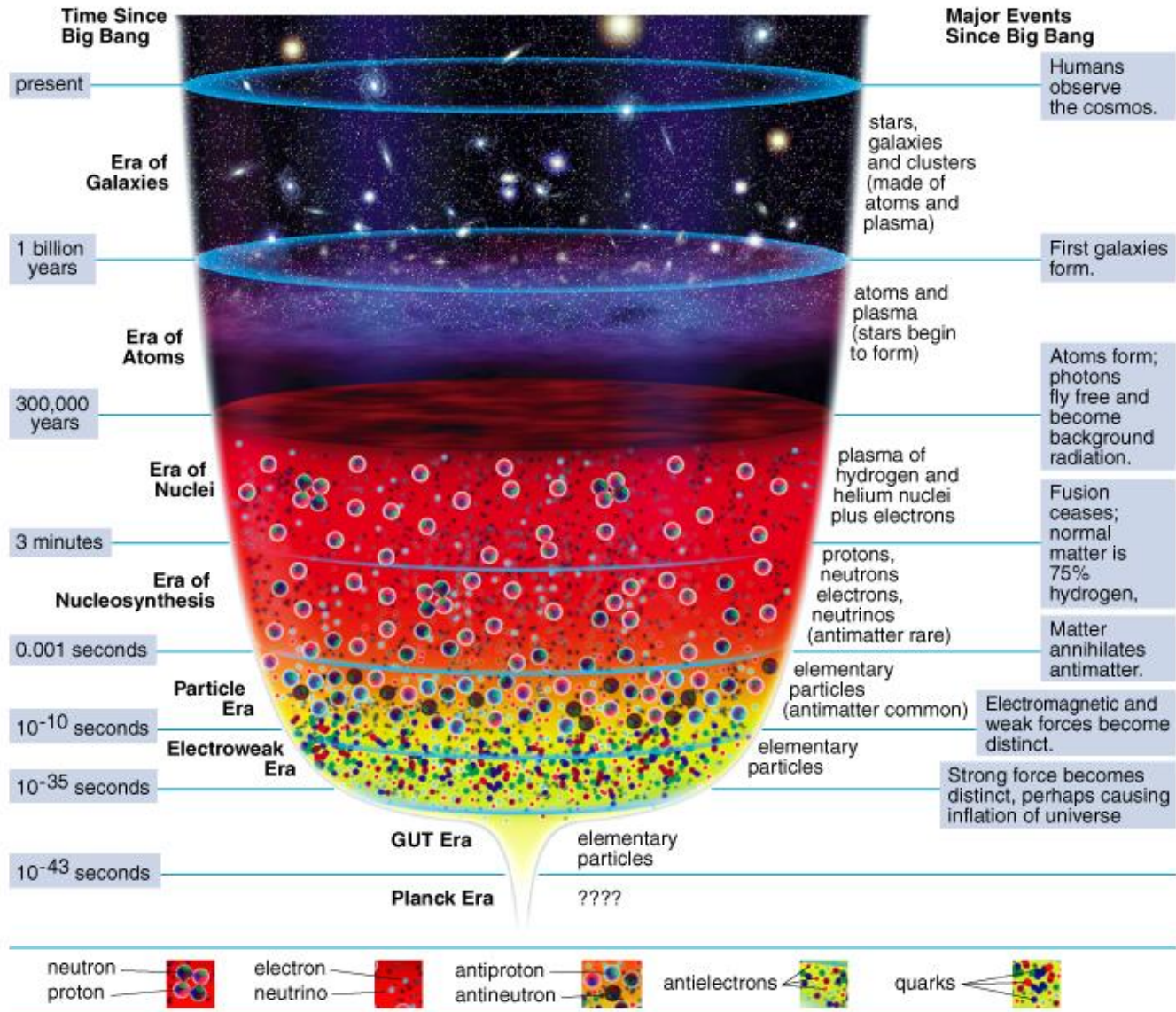
It is the purpose of this note to call attention to a phenomenon which will complicate the interpretation of the latitude effect. The variation in height of the maximum production region with geographic latitude introduces variations in the intensity of the hard component comparable to the variations presently attributed to the geographic latitude effect.

# Descubrimiento del fondo de radiación





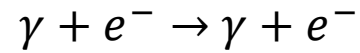
# Descubrimiento del fondo de radiación





# Época de recombinación

Scattering de Thomson



Camino libre medio del fotón es

Temperatura  $3 \times 10^5 K$

$$l = \frac{1}{n_e \sigma_e}$$

Sección eficaz  $\sigma_e = 6,65 \cdot 10^{-29} m^2$        $\Gamma = c/l = n_e \sigma_e c$

Con el universo totalmente ionizado

$$n_e = n_{bar}$$

De la densidad actual de bariones

$$n_e = n_{bar} = \frac{n_{bar(hoy)}}{a^3}$$

$$n_{bar(hoy)} \approx 0,22 m^{-3}$$

# Época de recombinación

para

$$a = 10^{-5}$$

$$\Gamma = 4,4 \cdot 10^{-6} \text{seg}^{-1}$$

Cada fotón sufre 3 scatterings por semana

Constante de Hubble

$$H(z) = 1,24 \cdot 10^{-18} \text{s}^{-1} (1 + z)^{3/2} \quad \text{con } z = 10^5$$

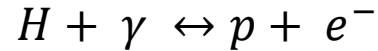
$$H = 2,1 \cdot 10^{-10} \text{seg}^{-1}$$

El universo se vuelve transparente

$$\Gamma = H$$

# Época de recombinación

Época de la recombinación



$$n_x = g_x \left( \frac{m_x kT}{2\pi\hbar^2} \right)^{3/2} \exp\left(-\frac{m_x c^2}{kT}\right)$$

$$g_s = 2 \text{ electrón} - \text{protón} \quad g_s = 4 \text{ átomo neutro}$$

$$\frac{n_H}{n_p n_e} = \frac{g_H}{g_p g_e} \left( \frac{m_H}{m_p m_e} \right)^{3/2} \left( \frac{kT}{2\pi\hbar^2} \right)^{-3/2} \exp\left(\frac{[m_p + m_e - m_H]c^2}{kT}\right)$$

$$\frac{n_H}{n_p n_e} = \left( \frac{m_e kT}{2\pi\hbar^2} \right)^{-3/2} \exp\left(\frac{Q}{kT}\right) \quad \text{Ecuación de Saha}$$

Parámetro de ionización

$$X \equiv \frac{n_p}{n_p + n_H}$$

0 bariones totalmente neutros  
1 bariones totalmente ionizados



# Época de recombinación

$$n_H = \frac{1 - X}{X} n_p$$

Neutralidad del universo  $n_e = n_p$

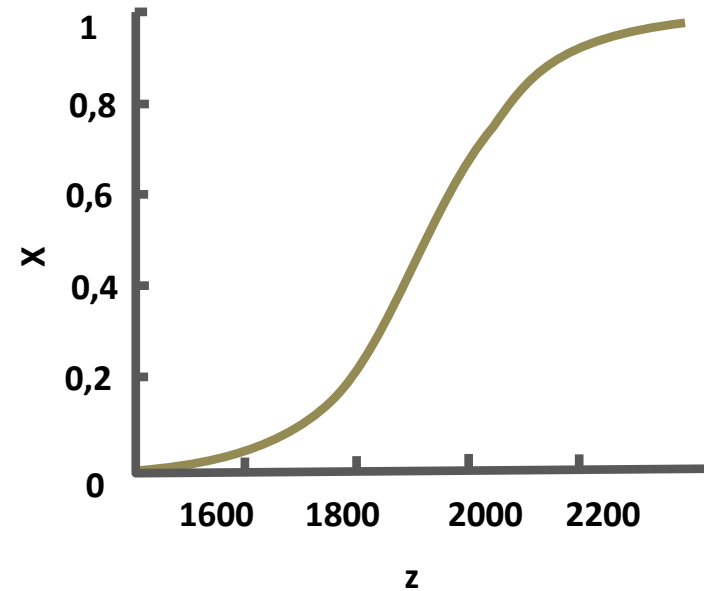
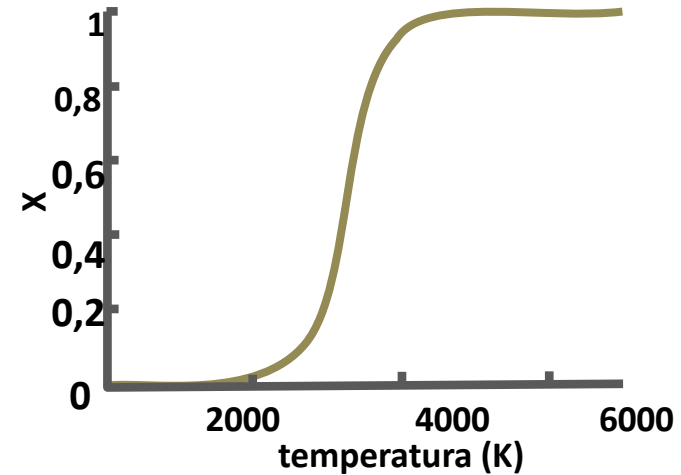
$$\frac{1 - X}{X} = n_p \left( \frac{m_e kT}{2\pi\hbar^2} \right)^{-3/2} \exp\left(\frac{Q}{kT}\right)$$

$$n_\gamma = 0,243 \left( \frac{kT}{\hbar c} \right)^3$$

$$\eta = \frac{n_p}{X n_\gamma} \cong 5,5 \cdot 10^{-10}$$

La función de Saha, resulta

$$\frac{1 - X}{X^2} = 3,84\eta \left( \frac{kT}{m_e c^2} \right)^{3/2} \exp\left(\frac{Q}{kT}\right)$$



## Época de desacoplamiento

$$\Gamma = n_e(z)\sigma_e c = X(z)(1+z)^3 n_{bar}\sigma_e c = 4,4 \cdot 10^{-21} s^{-1} X(z)(1+z)^3$$

$$H(z) = 1,24 \cdot 10^{-18} s^{-1} (1+z)^{3/2}$$

$$1 + z_{des} = \frac{43,0}{X^{2/3}(z_{des})}$$

De la ecuación de Saha

$$z_{des} = 1100$$

$$T_{des} = 3000K \quad \text{Edad del universo de 350000 años}$$

Entropía de un gas de bosones

$$S = VT^d$$

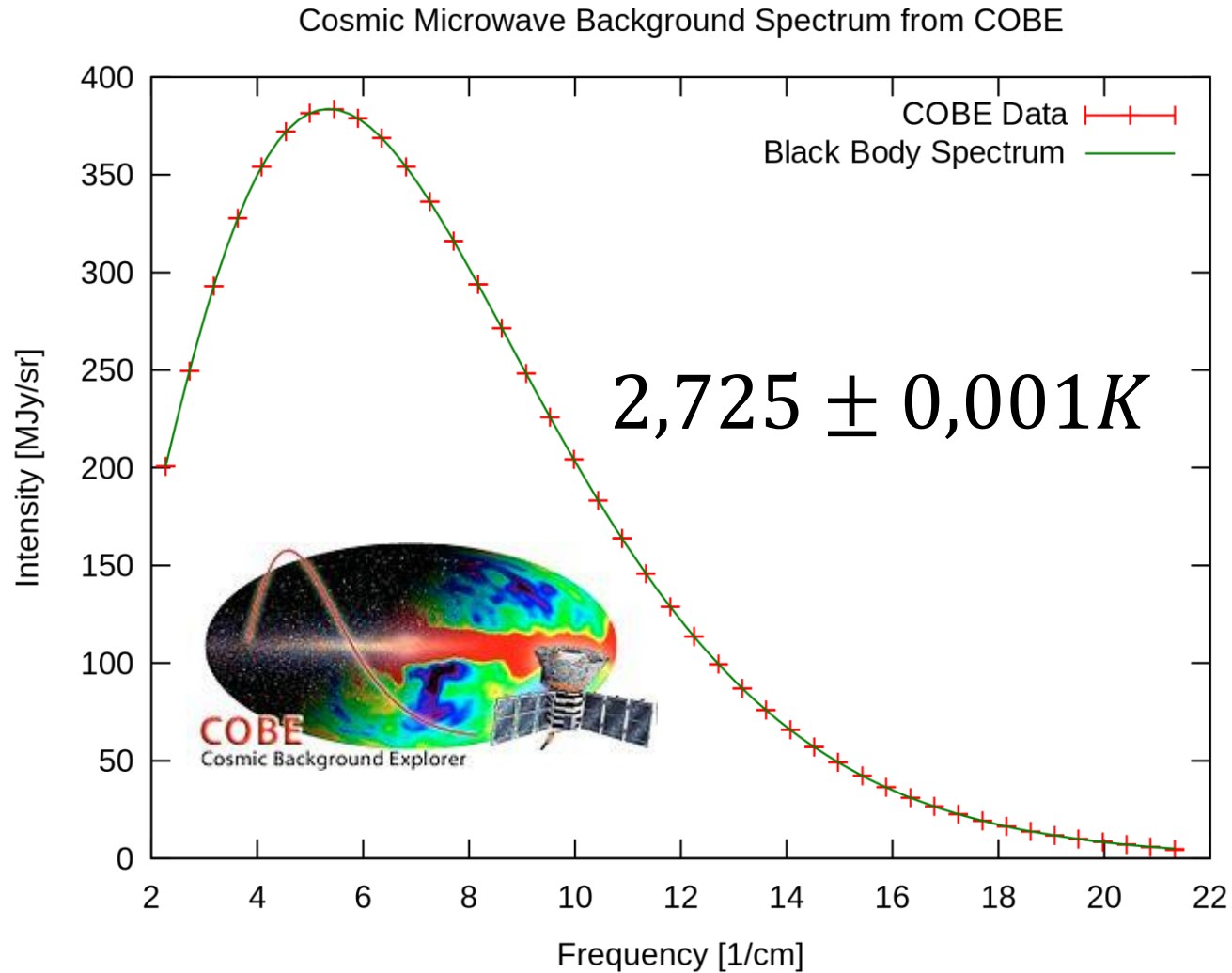
Expansión adiabática

$$VT^3 = cte \quad \text{con } d = 3$$

$$\frac{V_{T(hoy)}}{V_{T(des)}} = \left( \frac{T_{des}}{T_{hoy}} \right)^3 \rightarrow T_{hoy} \approx 5K$$

# COsmic Background Explorer

1989





# Propiedades de la radiación de fondo

Temperatura  $T = 2,725 \pm 0,001K$

Densidad de energía  $\varepsilon_\gamma = 4,17 \cdot 10^{-14} Jm^{-3}$

Densidad de fotones  $n_\gamma = 4,11 \cdot 10^8 m^{-3} \approx 411 \gamma_{CMB} cm^3$

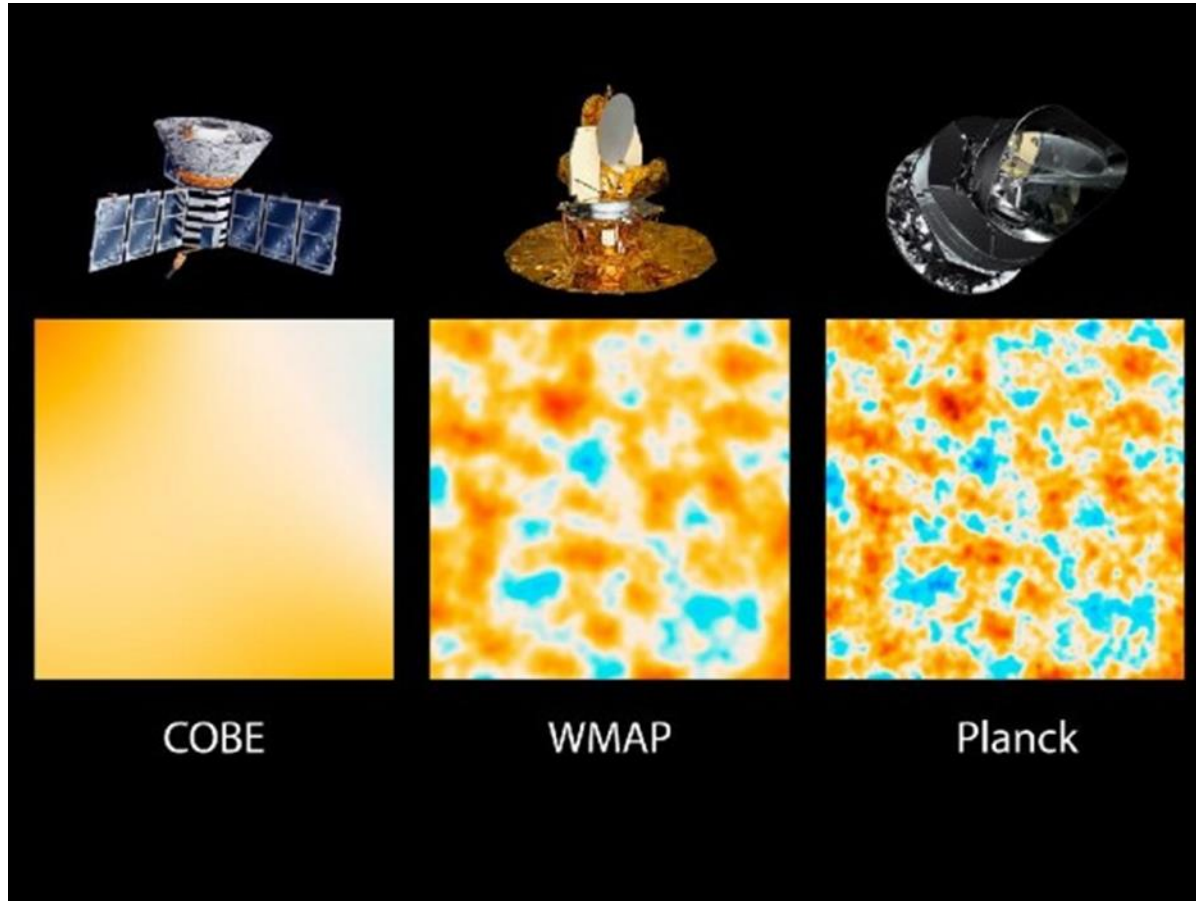
Energía media por fotón  $\langle \gamma_\gamma \rangle = 6,34 \cdot 10^{-4} eV \ll 10eV$

Longitud de onda  $1,06mm$

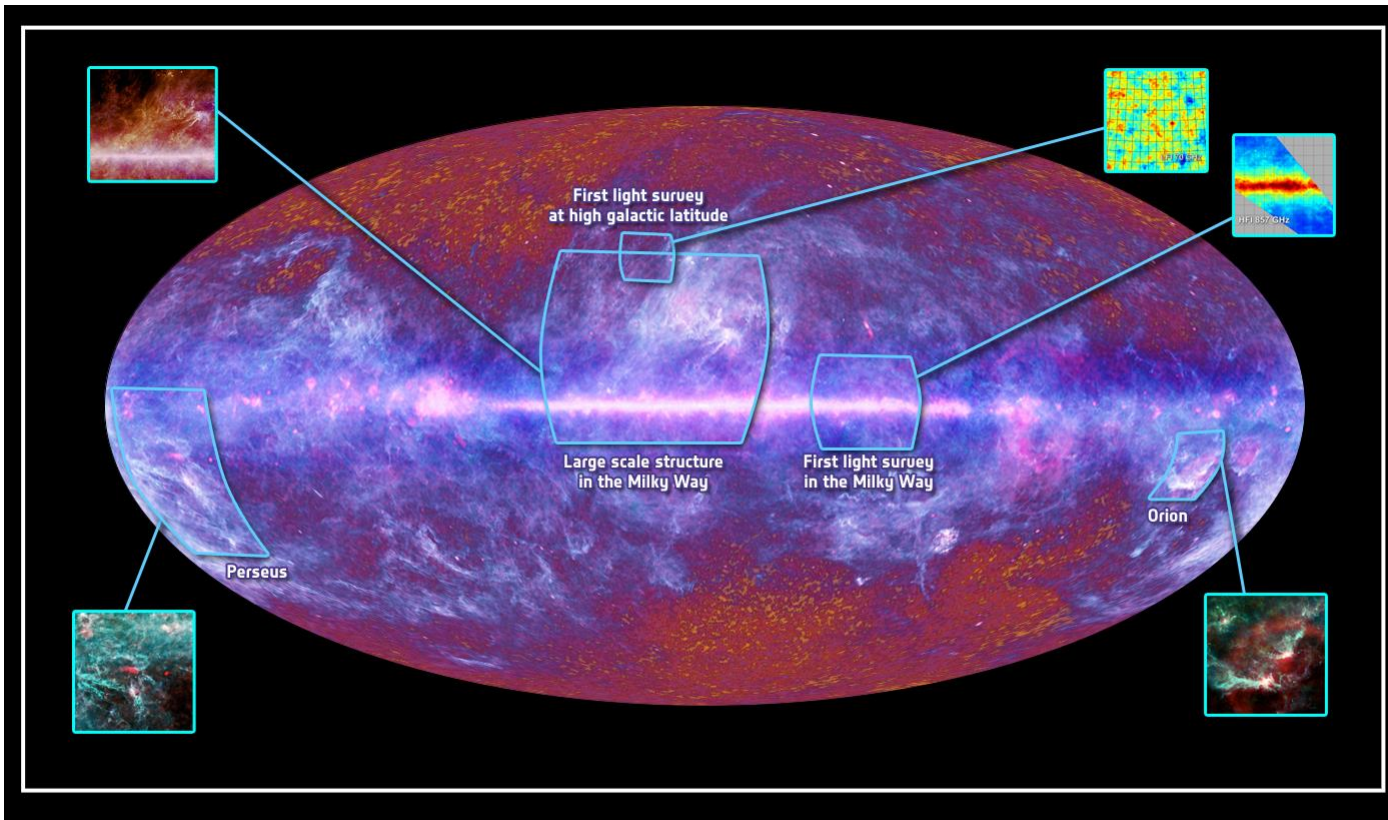
Frecuencia  $283Ghz$

# Misiones COBE, WMAP y Planck

2012



# Fondo de radiación cósmico



The Planck one-year all-sky survey

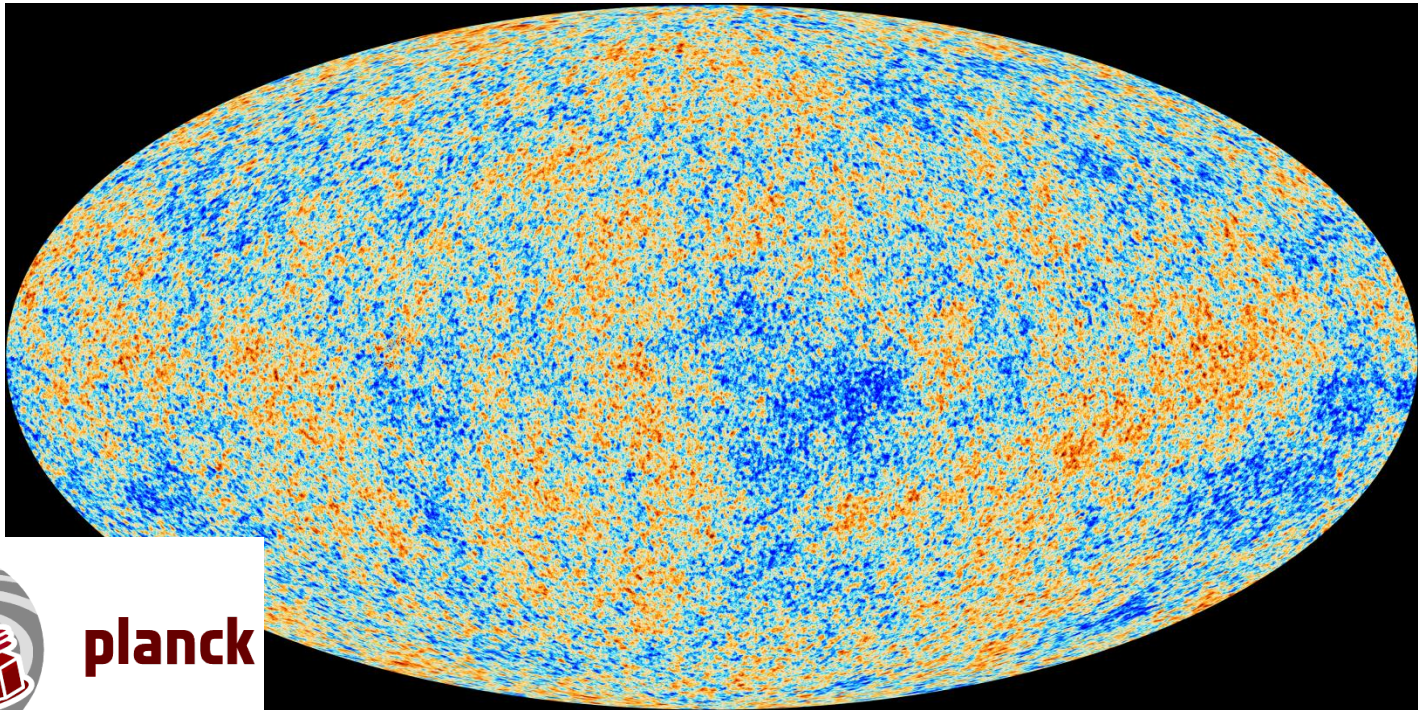




# Fondo de radiación cósmico

2012

$2,7255 \pm 0,0001K$



**planck**

# Fondo de radiación cósmico



**planck**

$$C(\theta) = \left\langle \frac{\delta T}{T}(n) \frac{\delta T}{T}(n') \right\rangle_{n \cdot n' = \cos \theta}$$

$$C(\theta) = \frac{1}{4\pi} \sum_{l=0}^{\infty} (2l+1) C_l P_l(\cos(\theta))$$

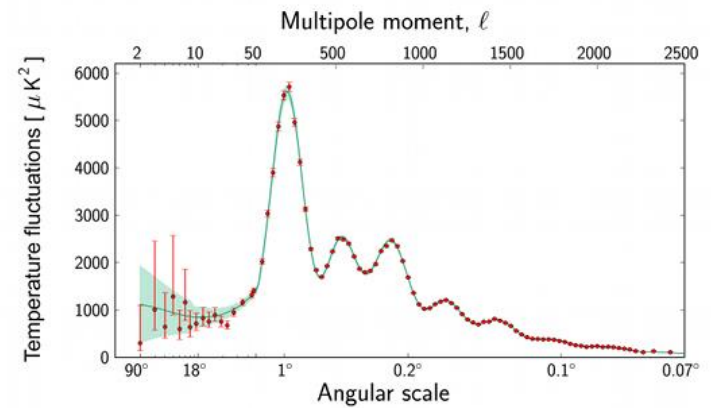
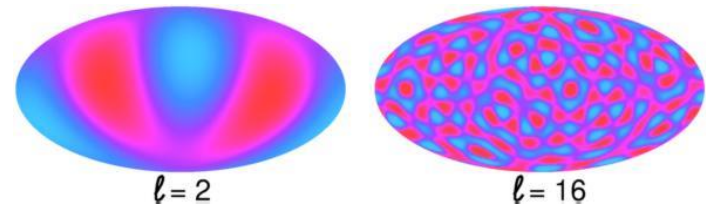
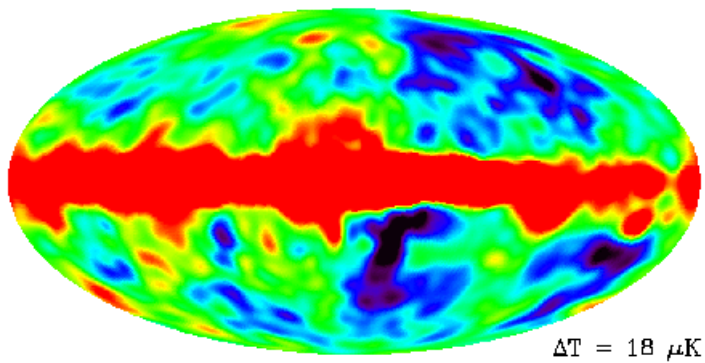
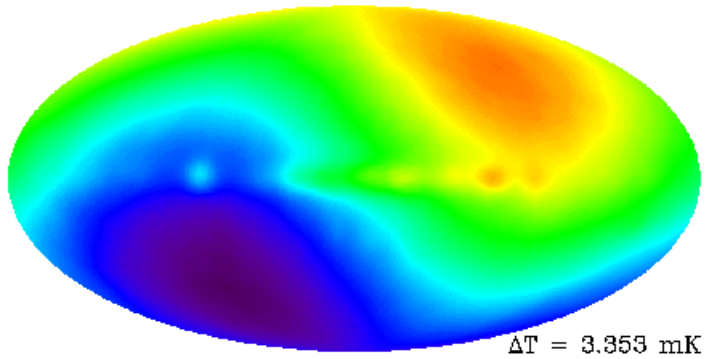
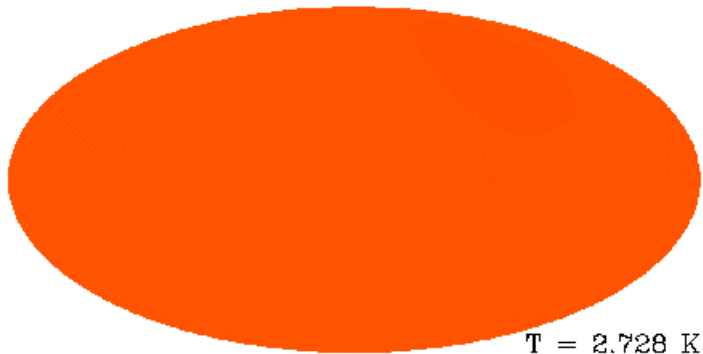
$$\theta = 180/l$$

$l = 0$  monopolo independiente del angulo

$l = 1$  dipolo variaciones 180

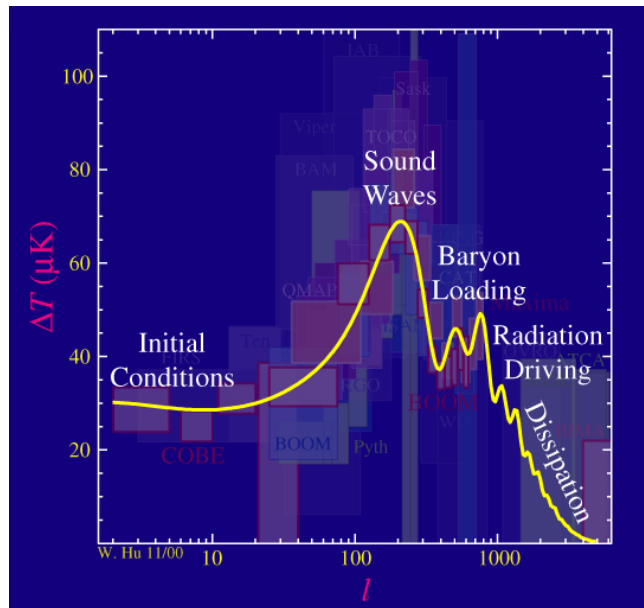
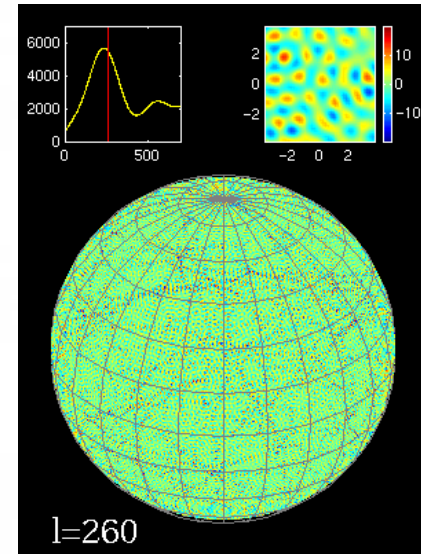
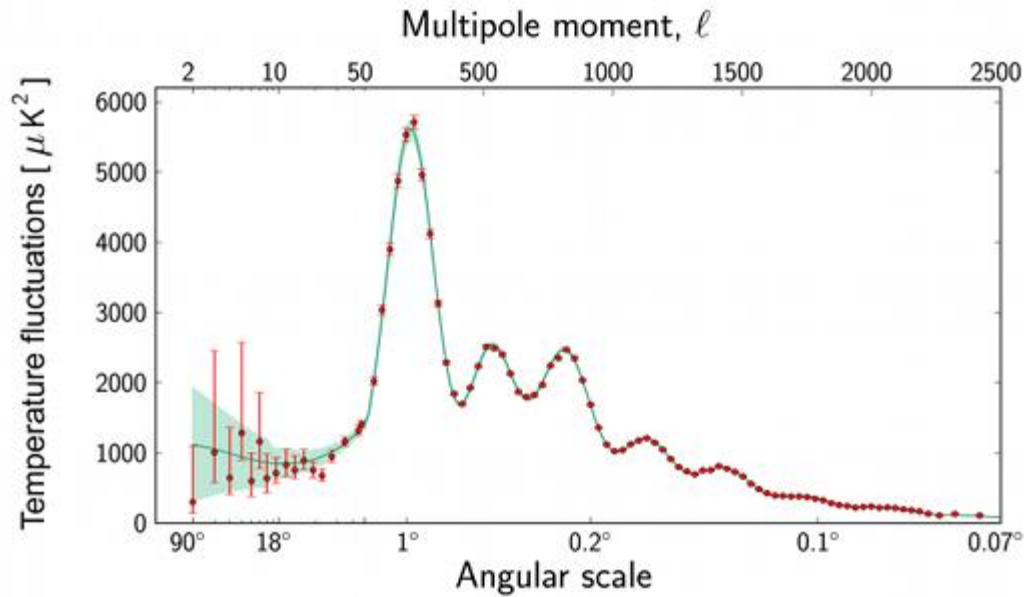
Para  $l > 2$  miden anisotropías menores a 180 grados, son muy pequeñas  $10^{-5} K$

# Fondo de radiación cósmico



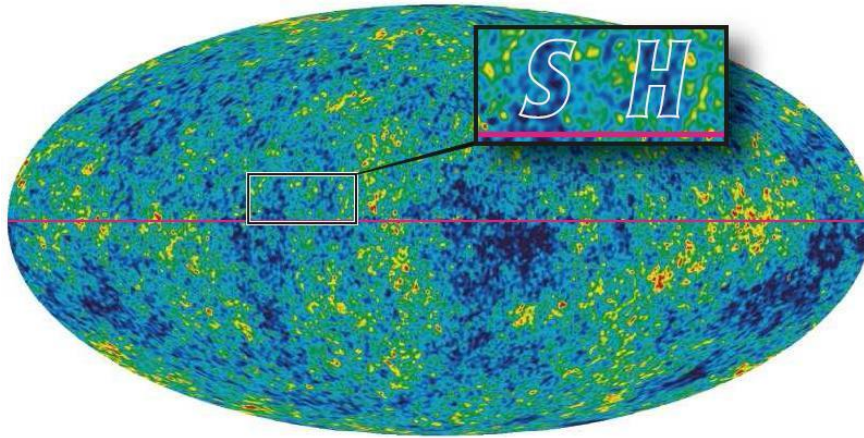


# Fondo de radiación cósmico

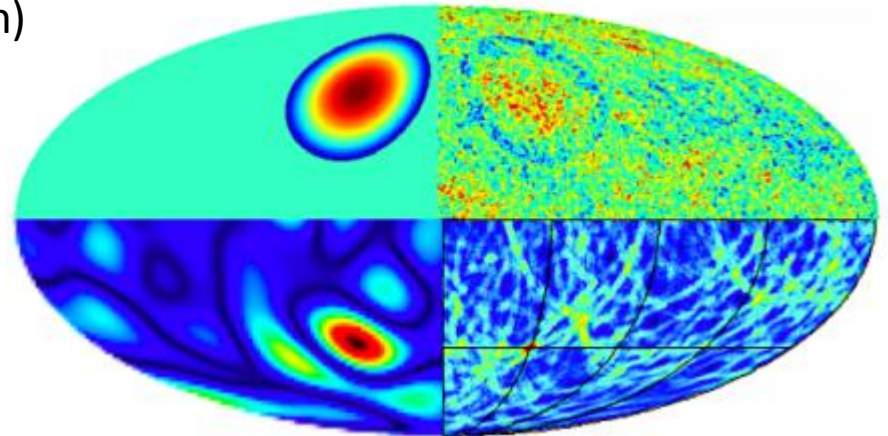


<http://www.astro.virginia.edu/~dmw8f/sounds/cdromfiles/index.php>

# Fondo de radiación cósmico



Las iniciales de Stephen Hawking  
(mapa ILC o Internal Linear Combination)



Roger Penrose. Colisiones con otros universos

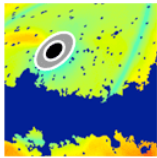
**V.G.Gurzadyan, R.Penrose.** *Concentric circles in WMAP data may provide evidence of violent pre-Big-Bang activity* arXiv:1011.3706.(2010).

**A. Moss, D. Scott, J. P. Zibin.** *No evidence for anomalously low variance circles on the sky.* arXiv:1012.1305 (2010).

# Fondo de radiación cósmico



## Synopsis: Collisions on the sky



S. M. Feeney *et al.*, *Phys. Rev. D* (2011)

### [First observational tests of eternal inflation: Analysis methods and WMAP 7-year results](#)

Stephen M. Feeney, Matthew C. Johnson, Daniel J. Mortlock, and Hiranya V. Peiris

*Phys. Rev. D* **84**, 043507 (2011)

Published August 8, 2011

### [First Observational Tests of Eternal Inflation](#)

Stephen M. Feeney, Matthew C. Johnson, Daniel J. Mortlock, and Hiranya V. Peiris

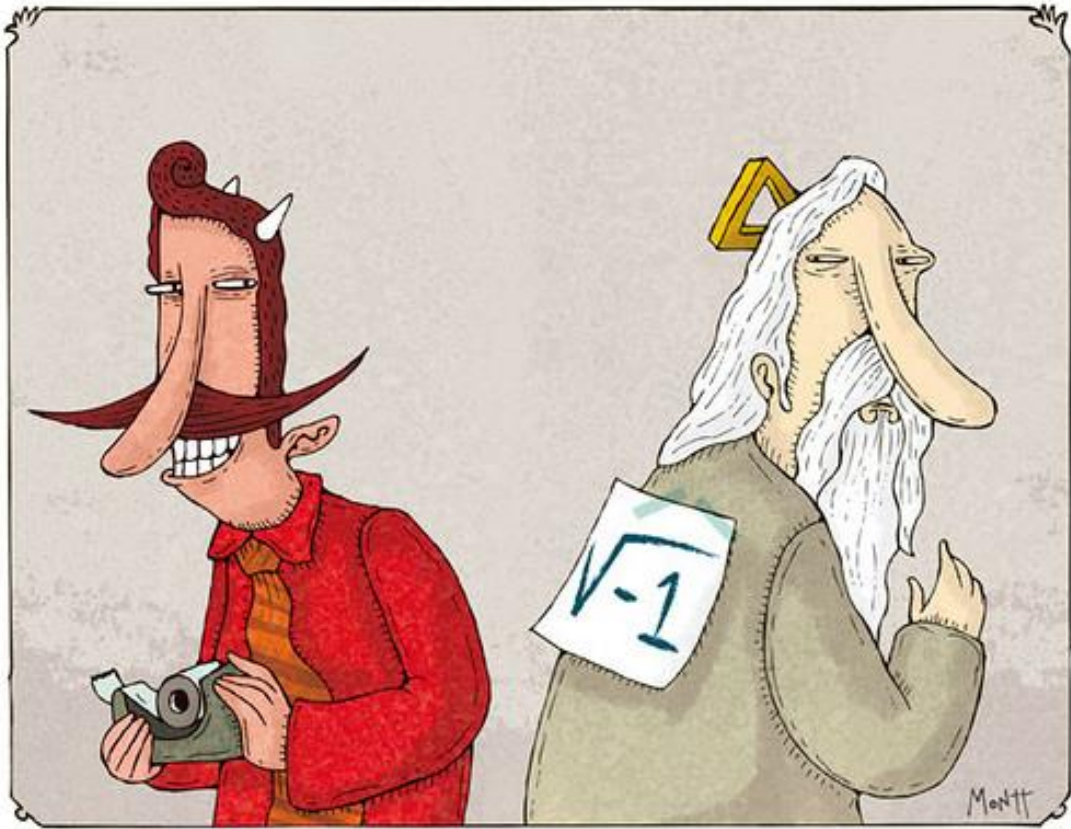
*Phys. Rev. Lett.* **107**, 071301 (2011)

Published August 8, 2011

A rapid expansion of the early universe—cosmological inflation—offers the best explanation so far of what astronomers observe. One flavor of this concept, called eternal inflation, involves nucleation of bubble universes (one of which we are in) in a continually inflating background. The collection of bubbles is known as the multiverse. Many aspects of this model would be difficult, if not impossible, to test, but one approach is to look for imprints of bubble behavior in the cosmic microwave background radiation. In a paper in *Physical Review Letters*, and a longer technical exposition in *Physical Review D*, Stephen Feeney at University College London and his colleagues analyze seven years of cosmic microwave background data from the Wilkinson Microwave Anisotropy Probe (WMAP) to hunt for signatures of eternal inflation.

The authors zeroed in on what might be the best target of opportunity, namely the effects of bubble collisions. Although direct observation of other bubble universes is not possible, the bubbles might have collided with one another and this bashing together might have left imprints on the cosmic microwave background, essentially itself a palimpsest of cosmic history. Feeney *et al.* carry out a statistical analysis of the full sky WMAP data, searching for specific distortions that may have been the wreckage of bubble crashes. They find no signatures of collisions, but are able to use this null result to put an upper limit on the number of bubble collisions the theory could predict and still be consistent with the data. The hope now is to continue the search for eternal inflation by applying the same tests to better data expected from the Planck satellite, which was launched in 2009. — *David Voss*

[Previous synopsis](#) | [Next synopsis](#)





LO ESTÁS HACIENDO MUY BIEN, AHARÓN.  
CUANDO TE GOLPEEN LA MEJILLA IZQUIERDA, OFRECE TAMBIÉN LA DERECHA.



UN DATO POCO CONOCIDO POR MUCHOS, ES QUE JESÚS  
FUE UNO DE LOS PEORES ENTRENADORES DE BOXEO DE PALESTINA.

MOISES VA AL BAÑO



LA CURIOSIDAD MATÓ AL GATO... Y 17.543 PERSONAS ALREDEDOR



SUMO PONTÍFICES





CADA CIERTA CANTIDAD DE SIGLOS, EL MUNDO DEJA DE GIRAR  
POR EL SIMPLE PLACER DE VER ACTUAR A LA INERCIA.





