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On the role of neutrino density in a closed expanding universe

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SEZIONE II

(Fisica, chimica, geologia, paleontologia e mineralogia)

Fisica. — *On the role of neutrino density in a closed expanding universe.* Nota di ANGELO AGNESE, MARIO LA CAMERA e ANDREA WATAGHIN, presentata (*) dal Socio B. FINZI.

RIASSUNTO. — Si considera la soluzione tipo radiazione delle equazioni della cosmologia. Vengono studiate le condizioni fisiche in cui questa soluzione può corrispondere alla realtà fisica. Viene prevista una radiazione relitto di neutrini e anti-neutrini che deve avere oggi $T \geq 43^{\circ}$ K.

The description of the Universe within the frame-work of general relativity may be obtained from the Einstein cosmological equations.

$$\frac{\dot{R}^2}{R^2} + 2\frac{\ddot{R}}{R} + \frac{c^2}{R^2} - \Lambda = -8\pi G \frac{P}{c^2} \tag{1}$$

and

$$\frac{\dot{R}^2}{R^2} + \frac{c^2}{R^2} - \frac{\Lambda}{3} = \frac{8\pi G}{3}\rho . \tag{2}$$

The equations:

$$p = \frac{\rho}{3}c^2 \tag{3}$$

and

$$\rho = \frac{b}{R^4} \tag{4}$$

introduce a particular model of the Universe, to which we shall refer as " radiation type " Universe.

The resulting equation is:

$$\frac{1}{R}\frac{dR}{dt} = \left(\frac{\Lambda}{3} - \frac{c^2}{R^2} + \frac{8\pi G}{3}\cdot\frac{b}{R^4}\right)^{1/2} . \tag{5}$$

The solution of the complete equation (5) has been obtained by A. Wataghin [1], and E. R. Harrison [2] and its implications in the case of a closed Universe have been analysed by A. Wataghin in [1] and by A. Agnese, M. La Camera and A. Wataghin in [3] and by A. Agnese in [4]. In these papers it has been shown that in the case of a closed " radiation type " Universe the radiation density must be $\rho \gtrsim 1.85 \cdot 10^{-29} g/cm^3$ (corresponding to a temperature $T \gtrsim 43^{\circ}$ K) and Λ should be different from zero [4] and probably of positive sign [3].

(*) Nella seduta del 19 novembre 1968.

However the term ρ appearing in eqs. 1 to 4 cannot represent gamma radiation, since, as it has been discussed above, the minimum density at the present time should be $1.85 \cdot 10^{-29}$ g/cm^3, while the temperature of the black-body type isotropic radiation observed by Penzias and Wilson [5] and Roll and Wilkinson [6] is 3° K. The density of matter ($\rho_{m,0} \simeq 10^{-30}$ g/cm^3) is also insufficient to close the Universe.

The simplest way of making possible a radiation closed model is to advance (see also [1]) the hypothesis that the dominating radiation responsible for the term ρ could be composed of neutrinos and anti-neutrinos. The system composed of these particles behaves as radiation (since their mass is zero and the degeneration parameter is assumed to be zero) (see [7]).

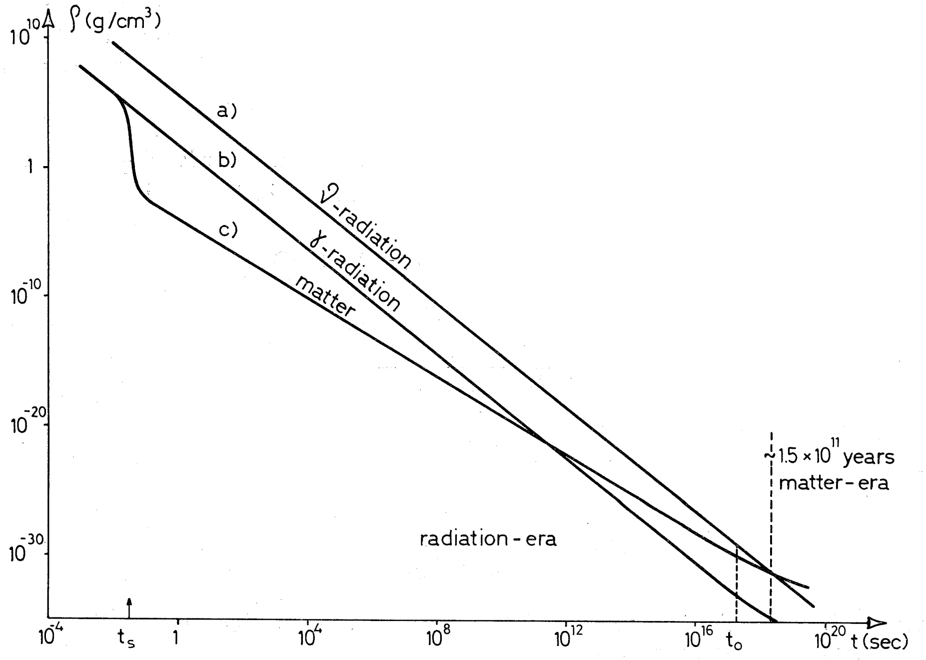

Fig. 1. – The Universe evolution in the case of a "radiation type" closed model: neutrinos, gamma and matter density as a function of the Universe age.

The situation is described in fig. 1. t represents the Universe age. Curve a) (neutrino fluid) has been calculated from:

$$\rho_\nu = \frac{b}{R^4} = \frac{\rho_{\nu,0} R_0^4}{R^4} = \frac{2 \cdot 10^{84}}{R^4} \text{ g/cm}^3 \tag{6}$$

and from eqs. (16) and (17) of ref. [1]. We obtain in the first approximation:

$$\rho_\nu = \frac{4{,}5 \cdot 10^5}{t^2} \text{ g/cm}^3. \tag{7}$$

Curve b) has been obtained from the relation:

$$\frac{\rho_\nu}{\rho_\gamma} = \frac{\rho_{\nu,0}}{\rho_{\gamma,0}} \simeq 3 \cdot 10^4. \tag{8}$$

The subscript ^{0} indicates calculations made for the present value of the Universe age ($t_0 \simeq 2 \cdot 10^{17}$ sec $\simeq 6.5 \cdot 10^9$ years) and for the present value of the Universe radius ($R_0 \simeq 10^{28}$ cm.).

The approximate Universe age at the separation time of gamma radiation and matter has been taken from [8]. ($t_s = 0.1$ sec.).

Curve *c*) (matter) has been obtained from:

$$\rho_m = \frac{a}{R^3} = \frac{\rho_{m,0} R_0^3}{R^3} = \frac{10^{55}}{R^3} \text{ g/cm}^3 \tag{9}$$

where the value of the constant a, has been obtained from:

$$\frac{\rho_{\nu,0}}{\rho_{m,0}} \simeq 20 = \frac{b}{a} \cdot \frac{1}{R_0} \cdot \tag{10}$$

The ratio ρ_γ/ρ_m at the separation time t_s may then be obtained from eqs. 6), 7) and 8).

$$\frac{\rho_{\gamma s}}{\rho_{ms}} \cong 5 \cdot 10^5. \tag{11}$$

The analysis of the separation of the curves *b*) and *c*) can be found e.g. in ref. [9]. It is due mainly to annihilation processes of barions.

The "ghost" neutrino radiation (curve a) cannot have been produced in the "lepton era" or successive eras ($t > 0.1$ sec) since according to our calculations it is difficult to obtain the ratio $3 \cdot 10^4$ (eq. 8) from mechanisms of annihilation of barions. It may however have been produced by the meson-decay and the decay and annihilation of the multi-Gev mass particles present in the hadronic era ($t < 0.1$ dec).

We finally observe that according to our model the Universe is at the present time still in the radiation era (neutrino radiation). The model also predicts that after 150 billion years the Universe will enter a matter era.

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