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A "chemical joke": the observable universe as an expanding ideal gas

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Abstract In the present work, are explored the consequences of to treat the observable universe as an expanding ideal gas. It is verified that the universe mass calculated by such approach agrees very well with accepted/reference values.

Keywords: Universe, ideal gas, big bang.

INTRODUCTION

In the present work, are explored the consequences of to treat the observable universe as an expanding ideal gas. As working hypothesis, each galaxy will be considered as "a particle" with no attractive or repulsive interactions with each other. Furthermore, it is proposed, as an working hypothesis, that the formation of our universe can be seen as an effusion process.

THE OBSERVABLE UNIVERSE AS AN IDEAL GAS

Nowadays, the number of galaxies in the observable universe is estimated as 175 x 10^9, that is (175 x 10^9)/(6.02 x 10^{23}) = 2.91 x 10^{-13} mols of galaxies.

From the ideal gas equation, PV = nRT (P in atm; V in litters; n = number of mols; R is the ideal gas constant = 0.0821 L.atm/mol.K; T in K) can be calculated the pressure value as: P= nRT/V = [(2.91 x 10^{-13}) x 0.0821 x 2.726]/9.2 x 10^{81} = 7.09 x 10^{-96} atm.

For the calculation, where employed the T value of 2.726 K as the universe temperature [1], and the volume of the observable universe was calculated applying the Hubble radius [1] in the sphere volume equation. The very small calculated pressure it is not the interstellar pressure (~1.32 x 10^{-13} atm) but the pressure that the "particles" (galaxies) exert on the "walls" of the universe. So, can be concluded that the expansion of the universe occurs without any contrary resistance.

In order to test the above calculated values, and taking into account that d (density) = m/V, the ideal gas equation can be expressed as P(m/d) = nRT, and so, the mass of the universe can be calculated as: m= nRTd/P, where the P value will be the previously calculated. The density of the universe is estimated as 2.05 x 10^{-26} kg/m^3 or 2.05 x 10^{-29} kg/L. So, m= (2.91 x 10^{-13} x 0.0821 x 2.726 x 2.05 x 10^{-29})/7.09 x 10^{-96} = 1.88 x 10^{53} kg, in really very good agreement with the accepted value of 1.89 x 10^{53} kg.

The obtained result is particularly exciting, taking into account that the pressure value employed was the calculated one, assuming that n = the number of mol of galaxies. Furthermore, the volume of the universe was estimated by using Hubble radius and, of course, the universe was assumed as behaving as an expanding ideal gas.

Before the big bang, the volume of the universe, V → 0 and so, P → ∞ which is a sound conclusion, and is in agreement with the progressive expansion of the universe (the inflationary model). So, it proposed, as an working hypothesis, that the driving force underneath the universe expansion is the pressure.

On the other hand, if we use the Planck´s temperature [1], that is, the temperature of the universe in the first moment after the big bang (1.41 x 10^{32} K), and take a volume, for example, of 1L, it is calculated a pressure of: P= nRT/V = [(2.91 x 10^{-13}) x 0.0821 x 1.41 x 10^{32}]/1 = 3.40 x 10^{18} atm

A very high one, and well above the pressures nowadays estimated for some stellar bodies.

AN EFFUSION PROCESS

As a working hypothesis, it is considered here that the expansion of the primordial universe (after the formation of the lighter chemical elements) can be seen as an effusion processes, that is, the matter that compose our universe was forced from a region of very high pressure (the big bang epicentre) to regions of lower pressure, with the consequent expansion of the universe.

By using the Graham´s effusion law: rate H/rate He = $[mHe/mH]^{1/2}$ = $[4/1]^{1/2}$ = 2. That is, the rate of effusion of hydrogen is twice the rate for helium. This value is in agreement with the fact that hydrogen and helium (the lighter elements) are the most abundant (H = 75% and He = 23%), in the universe. The ratio mH/mHe= ¼= 0.25, is close to the ratio of the abundances: 23/75 = 0.31. That is, the abundances are, for the lighter elements, inversely proportional to their masses.

The fact that the expansion of the universe it is associated with a decrease in its temperature (like a gas under expansion), it is also a characteristic that make the effusion hypothesis acceptable.

REFERENCES

[1] Coles, P.; Lucchin, F., *Cosmology*, Wiley, New York, 2002.