Some consequences of a spatially flat universe, the linear expansion universe R_h=ct

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abstracts

The standard cosmological model ΛCDM cannot respond to some important new results of modern cosmology. Challenges arise such as Microwave Background Uniformity, the Hubble Stress, the El Gordo collision or impossible galaxies ($z > 10$) that the standard cosmological model does not solve. On the other hand, other models are proposed as alternatives.

Professor Fulvio Meliá's linear expansion universe, R_h=ct, solves these challenges where the standard model fails. This model is based on the relationship R_h = ct where R_h is the gravitational horizon, which coincides with the Hubble radius, "t" is the age of the universe and "c" is the speed of light. Although the model is already theoretically based [3], in this work we have obtained the constraint R_h = ct as a consequence of the spatially flat universe.

Keywords: R_h = ct universe, general relativity, cosmos

1.- The R_h = ct constraint in a spatially flat universe

We consider an isotropic, homogeneous and spatially spherical universe, which responds to the FLRW metric and which therefore expands. This universe has a certain energy density ρ at each instant of time. We are going to refer our calculations to an observer located in the center of it. We call R_h its gravitational horizon [1] and $M_{(r)}$ the mass, which comes from its energy density ρ, contained in a sphere of radius "r" centered at the observer's point.

We are going to calculate the kinetic energy and potential energy produced by the expansion of the universe for that observer considering that sphere. The increase in its kinetic energy, "ΔK", during the expansion process is given by [2]:

$$\Delta K = (4\pi r^2 \rho \Delta r)\,(\Delta r/\Delta t)^2/2$$

and the corresponding increase in its potential energy "ΔU", is given by [2]:

$$\Delta U = (-4\pi r^2 \rho \Delta r)\, GM_{(r)}/r$$

According to [2], in a universe dominated by matter, the curvature parameter of the Friedmann equation k is proportional to the sum of the kinetic energies, K, and potential energies, U, brought into play by the expansion, and this parameter is zero in a spatially flat universe:

$$k \sim (K + U)$$

$$k = 0$$

and using differential calculus:

$$\int_0^t dK + \int_0^t dU = 0$$

$$1 = dK/(-dU) = (dr/dt)^2\, r/2G\, M_{(r)}$$

Let's do the calculation for $r = R_h$:

$$R_h = 2G\, M_{(Rh)}/c^2$$

$$1 = (dR_h/dt)^2 R_h\, /R_h c^2$$

$$dR_h/dt = c$$

$$R_h = ct + \text{Const.}$$

Let's calculate the value of the Const.:

For a time, t = o, $R_h = 0$, then Const. = 0

Thus, the following equation is obtained:

$$\mathbf{R_h = ct}$$

We have obtained the constraint that characterizes the universe of linear expansion $R_h = ct$ as a consequence of the zero value of the curvature parameter of the Friedmann equation, that is, of a spatially flat universe.

2.- Conclusions

Of the alternative models that are proposed to update the standard cosmological model, the linear expansion universe responds very well to the new challenges that the cosmos reveals to us today. This model is based on the study of the so-called "cosmological horizon" R_h and in the equation that characterizes it, the R_h=ct constraint. Although the model was already theoretically based [4], deducing that it is also a consequence of a spatially flat space, as our universe seems to be, is the result that we have achieved here.

References

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[3] Melia, Fulvio. The Friedmann-Lemaitre-Roberson_Walker metric. Modern Physics Letters. 2022; Vol 37 (3)