Is it necessary to modify the age of the universe due to the ages of the most distant galaxies that are now being discovered?

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Abstract

The recent discoveries of distant galaxies with a redshift $z > 10$ seem to call into question the estimate of 13.8 billion years for the age of the universe. The age of some of these galaxies is estimated to be close to or even greater than the age of the universe, a result that seems impossible to make compatible with the estimated age of the universe in the Standard Model. Therefore, the scientific community is studying the possibility of modifying the current value of this age and is reviewing the procedures that led to its current estimate. We therefore ask ourselves whether, with a universe age of 13.8 billion years, we can measure intergalactic distances greater than 13.8 billion light-years. The answer we arrive at in this work is that, theoretically, it is possible to measure significantly greater intergalactic distances in our current universe without needing to modify the age of the universe. We have reached this conclusion by studying the consequences that the spatial curvature of our universe has on the estimation of these distances. First, we determined the sign of the spatial curvature of the universe at present. We then developed a cosmology consistent with that sign, and finally, we determined distances and times. The conclusion is that it is possible in our current universe to measure distances significantly greater than its age in light-years allows, making current experimental results compatible with the value of the age of the universe.

Keywords: Universe Age, Cosmology, distant galaxies, General Relativity

1.- Why is our universe currently closed?

In FLRW metric cosmological models, the shape of the universe is determined by the sign of the spatial curvature. This value of “k” can be +1, 0, -1, and depending on it, the universe is either closed (k=+1) or open (k=0, -1). We show below that, according to Friedmann's equations, and for these to be compatible with the change in trend that the Hubble parameter, H, has had over the last 6 billion years, going from decreasing to increasing, it is necessary that, in the era of the universe dominated by dark energy, current era, the sign of the spatial curvature be positive, that is, k=+1. Thus, our universe is currently closed, finite, and has the shape of a hollow 3-sphere.

1.1 Introduction

Given the Friedmann equations, [1], of the FLRW metric, (ρ = Joules/m^3):

$$H^2 = \left(\frac{a'}{a}\right)^2 = \frac{8\pi G\rho}{3c^2} + \frac{\Lambda c^2}{3} - \frac{kc^2}{a^2}$$

$$\left(\frac{a''}{a}\right) = -\frac{4\pi G}{3c^2}(\rho+3p) + \frac{\Lambda c^2}{3}$$

1.2.- Equation that relates the derivative of the Hubble parameter with pressure, energy density and the curvature spatial

According to the Friedmann equation, the equation of state, and taking into account the expression for the derivative of H, we have:

$$H' = (a'/a)' = (a''/a) - (a'/a)^2$$

$$H' = \left(-\frac{4\pi G}{3c^2}(\rho+3p) + \frac{\Lambda c^2}{3}\right) - \left(\frac{8\pi G\rho}{3c^2} + \frac{\Lambda c^2}{3} - \frac{kc^2}{a^2}\right)$$

$$\mathbf{H' = -\frac{12\pi G(\rho+p)}{3c^2} + \frac{kc^2}{a^2}}$$

equation of state: w= p/ρ

$$\mathbf{H' = -\frac{12\pi G\rho(1+w)}{3c^2} + \frac{kc^2}{a^2}}$$

1.3- Study of H during the universe epochs using this equation

Let's study the sign of this equation in the different eras that make up the history of the universe. That is, during the radiation era, the matter era, and the dark energy era, which is the current one. Each of these eras is characterized by a different value of the equation of state parameter , w, (w=+1/3 in the period of universe dominated by radiation, w = 0 in the period of universe dominated by matter, w= -1 in the period of universe dominated by dark energy), and also according to experimental data [2], currently the term $\Omega_k = \frac{kc^2}{a^2}$ is very small, and its sign is still undetermined. Furthermore, according to recent experimental data, a trend change in the value of H has been observed as a function of the age of the universe, going from decreasing to increasing since 6 billion years ago. We, studying the equation derived from the values of w and these data, conclude that all these data are fully consistent with the FLRW metric as long as k = +1 is fulfilled, ruling out the other two possible values of k: 0 and -1. We explain this conclusion below:

First, we study the sign of H' according to the different values of w at different periods of the universe. We summarize these calculations and reasoning in the following table:

$$\mathbf{H' = -\frac{12\pi G\rho(1+w)}{3c^2} + \frac{kc^2}{a^2}}$$

Considering that the curvature term of the Friedmann equation is small compared to the other terms of the equation, the following will be fulfilled:

Period of the universe dominated by radiation, from its beginning until the year 360,000

w = +1/3

$$\mathbf{H'=-\frac{12\pi G\rho(1+\frac{1}{3})}{3c^2}+\frac{kc^2}{a^2}}$$

For k = 0, +1, -1. H´ will be negative. H will always be decreasing. It is not possible by this analysis to determine the sign of the spatial curvature in this period.

Period of the universe dominated by matter, from year 360,000 to 6 billion years ago

w = 0

$$\mathbf{H'=-\frac{12\pi G\rho}{3c^2}+\frac{kc^2}{a^2}}$$

For k = 0, +1, -1. H´ will be negative. H will always be decreasing. It is not possible by this analysis to determine the sign of the spatial curvature in this period.

Period of the universe dominated by dark energy, from 6 billion years ago until its end

w = -1

$$\mathbf{H'=\frac{kc^2}{a^2}}$$

For k = -1, H´ will be negative, then H will be decreasing.

For k = 0, H´ will be zero then H will be constant

For k =+1, H´ will be positive, then H will be increasing

It is therefore in this period of the universe dominated by dark energy that by observing the behavior of H in it we can determine the sign of the curvature in it.

We know from experimental data that for about 6 million years, the Hubble parameter has been changing its trend, from decreasing to increasing. That is, for the past 6 million years, the Hubble parameter has been increasing. This change in trend coincides with the transition from the period of universe dominated by matter to the period of universe dominated by dark energy, the current universe. Thus, according to our analysis of the Hubble parameter, these facts can only be explained if k = +1 in the dark energy period. That is, the spatial curvature is positive in the period of universe dominated by dark energy, the current universe.

2.- A cosmology with positive spatial curvature

2.1.- Introduction

The spatial curvature of the universe has been an important objective of study for Cosmology. The Mission Planck [2], measurements of the value of the curvature term in the Friedmann equation demonstrated that the spatial curvature is very small, but they were not able to determine its sign. This sign is very important for understanding the geometric and physical characteristics of our universe (its shape, its boundaries, its energy, etc.).

We have shown that the sign of the spatial curvature is positive (k=+1), for the universe in the period of universe dominated by dark energy, that is, the current universe.

As we demonstrated the relativistic universe with the FLRW metric, with positive sign for the spatial curvature implies, according to reference [3], that the spatial part of its space-time presents the geometric shape of a three-dimensional hollow sphere, that is, a 3-sphere, inserted in a four-dimensional space-time. That is to say, it is a closed universe, finite, without borders, in contrast to the universes of K=0. -1, which are open universes, that is, infinite.

We assume that in our equations, the total energy of the universe must be the same in the 3-sphere as in the observable universe, and that the energy density must be the same in the 3-sphere as in the observable universe.

With this assumption, we therefore require that the surface area of the 3-sphere be equal to the volume of the observable universe.

2.2.- Calculations in cosmology with positive spatial curvature

The 3-sphere geometrically constitutes the spatial part of our spacetime according to the FLRW metric and the positive sign of the spatial curvature. Let's determine its radius, relating it to the age of the universe.

Determination of the equation of the radius of the 3-sphere
r is the radius of the observable universe, $r = ct$
R is the radius of the 3-sphere
Volume of the universe = $4\pi r^3/3$
Surface of the 3-sphere $= 2\pi^2 R^3 = S^3$, [4]

Equating the volume of the observable universe with the surface area of the 3-sphere, we have a relationship between the radius of the 3-sphere, R, and the radius of the universe r.

$4\pi r^3/3 = 2\pi^2 R^3$
$R = (2/3\pi)^{1/3} r = 0,5964.r \cong 0,6\ r$
$R/r = 0,5964 \cong 0,6$
$R = 0,6\ r = 0,6,\ c.\ t.$

In the current universe, the radius of the 3-sphere is: (1)

t = age of the universe = 13.8 billion years [5]
c = 9,46.10^{15} m/year
ct = 13.8 billion light-years
R = 0,6 c t = 8,28 light-years
R= 0,78.10^{26}m

2.3.- Distance measurements in a universe of FLRW metric and positive spatial curvature

We start from a universe with a positively curved FLRW metric, as ours currently is, that is, a closed universe in the shape of a hollow 3-sphere, [3]. The distance between two points is given by the length of the geodesic joining them. Geodesics in the hollow 3-sphere are maximum circles. Thus, all geodesics in the 3-sphere will have a maximum length of L = 2πR, where R is the radius of the 3-sphere. In this work, we previously calculated the current radius of the 3-sphere (1), which turns out to be a function of the age of the universe and a value, R = 8.28 light-years. Thus, for an age of the universe of 13.8 billion years, it is possible to measure intergalactic distances in our universe of up to L = 2πR = 2π(8,28) = 52 billion light-years. Which makes the age of the universe compatible with the distances of the galaxies that are now being discovered.

4.- Conclusions

In this work, we have asked how it is possible to make the age of the universe of 13.8 billion years compatible with the ages of the most distant galaxies currently being discovered, which lead to age values even larger than the supposed age of the universe. To answer this question, we began by analyzing some geometric characteristics of our universe, specifically its shape. This shape is determined in the FLRW metric by the sign of its spatial curvature. We have shown that, during the period of the universe dominated by dark energy, this sign is necessarily positive. That is, at present, the spatial curvature of the universe is positive. This result implies that our universe has the shape of a hollow 3-sphere, with a radius of the 3-sphere that depends only on the age of the universe. Thus, the length of the radius of the 3-sphere depends on the age of the universe, but the lengths to be measured in the 3-sphere will depend on the lengths of the corresponding geodesics of the 3-sphere. The distances between two points on the 3-sphere are given by the arc length of the geodesic that passes through those two points. On a sphere, geodesics are maximum circumferences, and the maximum length of each geodesic is L = 2πR. Therefore, the maximum length between two points will be greater than the radius of the 3-sphere. According to the energy considerations we have made to fulfill the law of conservation of energy, this radius is given by R = 0.6(c.t), where t is the age of the universe. Solving the problem quantitatively for our universe, we find that for an age of 13.8 billion years, it is possible to measure distances of up to 52 billion light-years. In other words, the age of the universe is compatible with the distances of the most distant galaxies currently being discovered within a Standard Cosmological Model with positive curvature, a curvature that, as we have demonstrated in this work, is the current one in our universe.

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