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SHORT COMMUNICATION

A Simple Modification to Make the ΛCDM Model Compatible with the Ages of the Most Distant Galaxies that are Being Discovered

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Abstract

The recent discoveries of distant galaxies with a redshift $z > 10$ seem to call into question the Standard Cosmological Model's estimate of the age of the universe at 13,8 billion years. Some of these galaxies are estimated to be close to or even older than the age of the universe, a result that seems absurd. The scientific community is therefore studying the possibility of modifying this value. In this work, we ask whether, in a 13,8-billion-year-old universe, we can measure intergalactic distances significantly greater than 13,8 billion light-years. The answer found here leads to the possibility of measuring these intergalactic distances if we require a positive spatial curvature of the universe, that is, $k = +1$. We have studied a model of the universe with a FLRW metric, positive spatial curvature (k=+1) and an age of 13,8 billion years. This model theoretically explains experimental data concerning the distances of the most distant galaxies. A universe with a k=+1 spatial curvature during the current era, dominated by dark energy, is a plausible hypothesis according to previous work we published in this journal, and would not, in principle, contradict the Mission Planck considerations regarding the spatial curvature of the universe.

Keywords: Cosmology, Age of the Universe, Spatial Curvature, Distant Galaxy.

1. A Cosmology with Positive Spatial Curvature

1.1 Introduction

The spatial curvature of the universe has been an important objective of study for Cosmology. The Mission Planck [1], 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.).

The relativistic universe with the FLRW metric, with positive sign for the spatial curvature (k=+1), implies, according to reference [2], 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.

1.2 Let's Calculate the Radius of the 3-Sphere

To perform this calculation, we will apply the principle of conservation of energy as follows: We understand the observable universe to be the universe contained within the cosmological horizon, that is, in a sphere with radius $r = ct$, where "t" is the age of the universe. 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

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require that the surface area of the 3-sphere be equal to the volume of the observable universe.

The 3-sphere geometrically constitutes the spatial part of our spacetime according to the FLRW metric and the positive sign of the spatial curvature, [2]. Let's determine its radius, relating it to the age of the universe.

1.2.1 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 observable universe = $4\pi r^3/3$ Surface Area of the 3-sphere $=2\pi^2R^3 = S^3$, [3]

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.

$4\pi r^3/3 = 2\pi^2R^3$

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

R = 0,6 r = 0,6, c. t.

1.2.2 In the current universe, the radius of the 3-sphere is

t = age of the universe = 13,8 billion years [4]

$c = 9{,}46.10^{15}$ m/year

ct = 13,8 billion light-years

R = 0,6 c t = 8,28 billion light-years $R= 0{,}78.10^{26}$m

1.3 Distance Measurements in a Universe of FLRW Metric and Positive Spatial Curvature

We start from a universe with FLRW metric and positive curvature, that is, a closed universe in the shape of a hollow 3-sphere, [2]. 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 which turns out to be a function of the age of the universe and a value, R = 8,28 billion 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.

Thus, we have shown that in a universe with a FLRW metric and positive curvature (k=+1), which has the shape of a hollow 3-sphere and in which we have required that its energy density coincide with the energy density of the observable universe and its total energy coincide with the total energy of the observable universe, the radius R of the 3-sphere at any time is given by R=0,6.ct where "t" is the age of this universe. Particularizing it for the age of the current universe, 13,8 billion years, R = 8,28 billion light-ages. Already in this universe we have calculated the maximum distances to be measured that will correspond to the lengths of the longest geodesic. Since it is a 3-sphere, geodesics are great circles and therefore the maximum length of each geodesic is L=2πR. Particularizing for the universe of 13,8 billion years, the result is L=52 billion light-years. Thus, with a universe radius of 13,8 billion light- years, distances of up to 52 billion light-years can be measured in our FLRW metric universe model with positive curvature (k=+1). This distance covers all the ages of the galaxies that are currently being discovered, so we conclude that this model we propose is valid to explain the experimental facts of the most recently discovered galactic distances and ages without the need to modify the current value for the age of the universe estimated by the Mission Planck [4] at 13,8 billion years.

2. Conclusion

Our work concludes that considering our universe with positive curvature would solve the problem presented by the discovery of these new galaxies with ages very close to or greater than the age of the universe. The positive curvature of the universe, which implies a hollow 3-sphere shape for its spatial part, i.e., a universe in the shape of a hollow 3-sphere, entails the possibility of measuring distances much greater than its radius and on the order of the ages of the galaxies now being discovered without modifying the age of the universe, as paradoxical as it may seem.

The problem arises with some of the conclusions reached by Mission Planck regarding the curvature of space. It determines that $\Omega_k = 0.001\pm0.002$ and states that space appears to be flat. In this work, we agree with the value of Ω_k, but we do not share the conclusion stated below. The first thing we consider is that, according to our reference work [5], strictly zero spatial curvature is only possible in a space without matter. Matter curves space according to Einstein's equations, and therefore, flat space is only possible in the absence of matter. Thus, Mission Planck claim that space is flat must be understood broadly, that is, in the sense of being a space with very little curvature. The value of Ω_k they propose is consistent with this. Furthermore, this value does not determine the sign of the curvature; that is, it may well be positive, a small positive value, as stated in this work. In a previous work published in this journal [6], we demonstrated that the sign of spatial curvature during the period of the universe dominated by dark energy, that is, the current one, was positive. From all this, we affirm our hypothesis of a universe with a small positive curvature for our current universe, which would explain, within the Standard Cosmological Model and without needing to modify its age, the ages of the most distant galaxies that are now being discovered.

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